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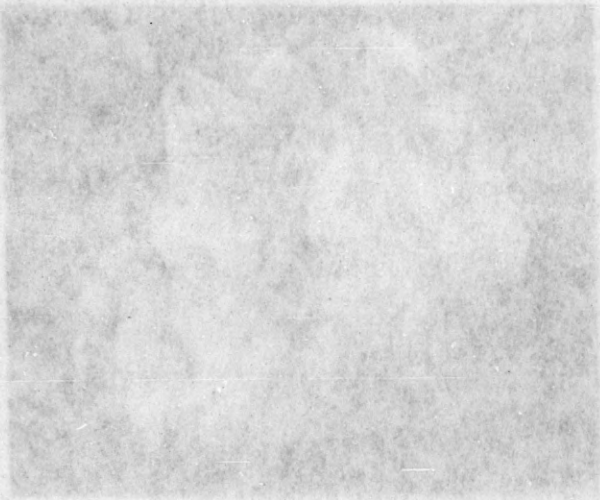
Published by

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA
Prince and Lemon Streets, Lancaster, Penna., and
Benjamin Franklin Parkway at Twentieth St., Philadelphia, Penna.

SIX DOLLARS PER YEAR (Foreign Postage Additional) **SINGLE NUMBERS, SIXTY CENTS**

Indexes to the semi-annual volumes of the JOURNAL are published with the June and December numbers. The contents are also indexed in *The Industrial Arts Index*.



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Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 238 AUGUST, 1944 No. 2

ON SOME COMMANDING ASPECTS OF THE AMERICAN MAN OF BUSINESS.*

With an introductory sketch of the technical side of the life of Charles Day

BY

MORRIS LLEWELLYN COOKE,

Consulting Management Engineer, Philadelphia.

PART 1.

The Charles Day Memorial Lectureship of the Franklin Institute is a fitting tribute to a devoted public servant, an engineer skilled in the fundamentals as well as in the nuances of the engineering profession; a tactful, modest and inspiring leader in the world of large affairs; and a cultivated gentleman, morally resolute when standing at the cross-roads. Perhaps the fact that your speaker was not associated professionally with Charles Day may make it possible the more accurately to appraise his work and so key to his stature the lectures which through the years will in his memory be heard in this hall.

After graduating in Mechanical Engineering at the University of Pennsylvania in 1899, Day entered the employ of the Link Belt Company and in doing so came under the influence of two distinguished engineers—loyal Philadelphians and great Americans—first, James M. Dodge, president of the company, who had been for many years vice-president of The Franklin Institute, and second, Frederick W. Taylor, the acknowledged Father of Scientific Management, whose methods of management were being introduced and developed at the Nicetown plant. When Day left Link Belt in 1901 he formed a partnership with Kern Dodge, our well-known fellow-townsman, who had also served his

* Initial Lecture under the Charles Day Lecture Foundation of The Franklin Institute of Philadelphia, given in the Hall of the Franklin Institute, May 17, 1944.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

apprenticeship in Scientific Management at Link Belt. The new firm practiced as "Modernizing Engineers." These young men were among the very first to announce, and with some publicity, that a new type of engineering, i.e. management, was at the service of industry.

Then followed in 1911, in the firm of Day and Zimmermann, Day's long association with the late John E. Zimmermann, at the time of his death president of the United Gas Improvement Company. The first important interest of "D and Z," as the firm came to be known in the business world, had to do with the management of the Penn Central Power and Light Company. An outstanding accomplishment here was the development of a wholly new system of cost finding adapted to, and in its essentials quite generally adopted later by, the electric utility industry.

When war was declared in April 1917, the Scientific Management group, under the leadership of Henry P. Kendall, after a short campaign convinced the Government through the General Munitions Board that its plans for storage at home and abroad were quite inadequate. A Storage Committee, of which Day was one of two full-time members, was appointed and far-flung activities initiated. Storage techniques were developed, schools for storage workers were conducted, port facilities arranged for, and in the end, $300,000,000 expended in storage facilities. Day went to Europe twice on special commissions appointed by President Wilson, and toward the close of the war was made a member of the War Council of the Army—the only civilian sitting on a Board composed of the highest ranking officers. Day's first assignment for work with the Federal Government was his appointment in 1911 by Secretary von Meyer as a member of the Civilian Board on the Management of Navy Yards. This involved a study of the U. S. Atlantic fleet at battle practice.

Perhaps one of the most interesting phases of Day's career was the many-sided part he played in the radical revision of the organization of the University of Pennsylvania after President Thomas S. Gates took the helm. This service began with his election as a Trustee in November, 1920. He was a vice-president of Franklin Institute for several years, a member of its Board for over 20 years and at the time of his death a director of the United Gas Improvement Company, of the Fidelity-Philadelphia Trust Company and of the Pennsylvania Railroad.

Reviewing the foregoing record in the effort to discover what features resulted in contributions to American engineering, I think first place must go to the recognition of cost finding as a necessary and quite inseparable feature of management on the Penn Central public utility property, serving the geographical area centering in Altoona. It will be recalled that at the time this work on the Penn Central was started—about 1910—the idea was generally entertained that the present-day concept of cost finding in public utilities was impracticable.

Cost *studies* had frequently been made—especially on the railroads. But up to that time no costs taken from the books as a month to month and year after year routine had been attempted. Nor had the regulation of operations by definitive costs been attempted.

The meeting of the Society to Promote the Science of Management, at which Charles Day presented what was considered at the time an unusually notable paper on "Scientific Management in the operation of a Public Service Corporation (illustrated)," was held in Ann Arbor, Michigan in 1916.

Among the main features of the management of Penn Central, as explained by Day on that occasion, were:

1. Functional organization.
2. Mnemonic classification and symbolization of every function and "work place," including not only main- and sub-circuits but also each pole and other physical unit.
3. The conduct of all operations through work orders, including even such units of work as maintenance of poles and other physical properties, every job being identified as to character, unit, time, rate, etc.
4. A system of cost analyses and summaries collated by tabulating machines identifying the costs by units and groups.
5. Practicability of ascertaining the costs of distribution as well as of generation and transmission.
6. A suggested theory of retail rates novel for its day and not too far from today's accepted practice.

Day held as do nearly all good managers today that a proper system of accounts must have a definite relation to plant operation. In other words, accounts are only means to an end.

That Day never got around to editing his paper for publication was due to circumstances over which he had no control and is much to be regretted. The influence of its verbal presentation, however, was immediate. Visitors and correspondence galore resulted. The late Joseph B. Eastman, administrator of wartime transportation in World War II, and at the time a member of the Interstate Commerce Commission, came to Philadelphia with some of his ranking associates in the work of railroad valuation and regulation to study the methods. This visit resulted in a series of hearings before the Interstate Commerce Commission, in which representatives of many industries—paper, printing, building construction, metal working, milk, and textiles, among others—gave testimony as to the routine ascertainment of costs and their utilization in administrative and managerial decisions. A notable report by John H. Williams on railroad cost finding was a further outcome.

Day always looked upon brief, accurate and understandable reports as an essential feature of every task, and he was skilled at drafting them. Early in 1916 he wrote to me asking for:

"criticisms upon the form which we have adopted for our reports on public service properties. We have striven," he said, "to divide our report proper under logical headings and to make the text as 'readable' as possible without failing to cover all essential facts."

Reporting of this type struck a new note in a field very much needing it.

Day's commercial reporting also exerted a strong influence in important circles. It came at a period when American industry was being scaled up both by mass production and widespreading consolidations. These reports chiefly made at the behest of banking interests were characterized by frankness, keen analysis of the underlying conditions, technical competence, intriguing formats and general dependability. Reporting of that day too frequently was made to serve predetermined ends—sometimes to support illicit promotions.

On returning from one of his trips to Europe during World War I, as one of a large mission, President Wilson requested from each member, excepting the chairman, a single page report. Such a challenge Day was well qualified to meet.

Lastly, Day made a definite contribution to engineering progress in his early espousal of the cause of Scientific Management, a system for the control of all types of human endeavor which, notwithstanding its present world-wide acceptance, had to fight for recognition up to the time of World War I. Day's contribution lay not only in his competent application of the principles of Scientific Management to enterprises coming under his influence or control, but in his writings and in the part he took in launching the first society The Society to Promote the Science of Management.

"Industrial Plants"[1] under Day's authorship came out just about the time when public interest as to Scientific Management was first aroused through the widespread publicity that followed the Brandeis rate case. The book was largely devoted to the construction and layout of industrial plants as an aid to logical routing of the work. It was an early recognition in the developing mass production era, of the principle that purpose (or product) determines functions and that functions determine the kinds and forms of facilities required.

May I close this all too summary outline by quoting from a recent letter from Thomas S. Gates, Chairman of the Board of the University of Pennsylvania, and most heartily endorsing it:

"It is never an easy task to adequately evaluate the life of a friend. I think of Charley as a courageous soul who went through life at full speed, an idealist whose mind was master of his fate. Therefore, the contacts he made were always paths toward a larger plan. All of us who knew and worked with him are grateful for the happy years we spent together on life's great highway."

[1] "Industrial Plants, Their Management and Construction," by Charles Day, a volume in the Works Management Library, *The Engineering Magazine*, New York, 1911.

PART 2.

My lecture—really a very informal talk—is "On Some Commanding Aspects of the American Man of Business," the term "business" being used in a broad sense to include industry, commerce and the other great sectors of our economic life. I might just as well include my own profession of engineering because, in their relations to the public, between engineers and business men it is difficult to make meaningful distinctions.

My subject grows directly out of the situation—local, national and international—in which we Americans find ourselves. Conceding everything which the cultured must to the teachings of the past, and being as optimistic as possible about the drift in current events, yet, viewing the future, who can be blind to the baneful possibilities or so enlightened as to spell out its meaning and lay down rules of action. We hope, we trust. But it is generally admitted that we are on new ground with no stakes set.

Especially in periods of stress the people turn for guidance to leaders who reflect the spirit of the times. This leadership on occasion has come from the learned, as in ancient Greece. At other periods it has been religious in character. More frequently of course the military has dictated the course of public and private action as in present-day Germany.

Increasingly since the Civil War business has become the dominant note in American life. Nor is its hold on the imagination of our people likely to be lessened in the immediate future in view of its achievement in making our country the widely acknowledged "arsenal of democracy" in World War II. So the leadership in meeting our quite undetermined future will, in very large measure be dictated by business as it reflects the thinking of individual business men. My interest on this occasion is not in specific issues but rather on certain aspects of the life of the individual business man which may help to make his influence commanding, i.e., educationally and otherwise convincing and therefore compelling, in the councils of our people.

Were I to choose the equivalent of a text, it might well be "Four Pennsylvania Railroad Men" because I owe to William Henry Baldwin, Jr., Samuel Rea, Thomas S. Gates and Charles Day—all of them associated with the Pennsylvania—a considerable debt of gratitude for having afforded me valuable examples of commanding personal and public conduct. A strong influence in my early years was a book[2] entitled "An American Citizen," an inspiring biography of a truly great American—William Henry Baldwin, Jr., president of the Long Island Railroad, a P.R.R. subsidiary. I discovered on re-reading this book recently

[2] "An American Citizen, The Life of William Henry Baldwin, Jr." By John Graham Brooks. Houghton, Mifflin Co., 1910.

that it is as pertinent to the problems of this day as it was to those of 25 years ago. As Director of Public Works of Philadelphia I was in touch with Mr. Rea, then president of the Pennsylvania, on matters affecting the joint interests of city and railroad. I came to have the highest respect for his impeccable regard for the niceties of behavior in reconciling conflicting claims. And when a very young man I was privileged to know of a high-minded action taken by Thomas S. Gates in a matter of concern to himself and others, and recall remarking at the time, "I will never have to re-assess Tom's standards of conduct." His whole life has been of a piece, benefiting public and private relationships alike. As for Day, he taught me many a lesson as to how it is possible for right-minded Americans to fulfill public and private trusts even under difficulties. Any nation capable of producing four such broadly cultured and technically competent citizens is to be congratulated. Their lives afford a dependable background for my theme.

In discussing a few of what I take to be the characteristics of competence in American business leadership I must disclaim anything approximating the philosophical in my approach. What I shall say grows out of nearly 40 years of practice as a consulting management engineer involving contacts with politicians, publishers, industrialists, lawyers, teachers, labor leaders and other representative varieties of American citizens. Again, in what is said I have tried to avoid even seeming to criticize what is. Criticism is always easy. My thought has been rather to suggest further developments in the sometimes overlooked sources of power in the business man's equipment as he girds himself for greatly increased responsibilities.

ON READING.

Most of the business men whom I know personally appear to spend a reasonable part of their time in what is sometimes called solid reading. But a broad study conducted recently by a prominent advertising agency as to the reading habits of American business men shows that relatively few of them read books of any kind. The head of one of our most important enterprises operating from coast to coast reported "the magazine *Life* and the newspapers" as the extent of his reading. In a similar quest the professor in charge of a numerous class in one of Philadelphia's most important graduate schools took a poll as to the reading habits of these students. He discovered that almost without exception the group read the *Saturday Evening Post*, a few read the headlines and the sports pages in the newspapers, but not one of them did any serious reading outside that demanded by the curriculum. This particular teacher was of foreign origin and had had all his formal education abroad. But practicing in a rather narrow specialty, he had felt the necessity for some means of keeping his outlook broad. To meet this need he had chosen each year, and through many years,

a different subject, not in any way related to his breadwinning and professional life, for special and out-of-hours reading and study. One can imagine that with subjects ranging from Assyriology and archeology to dramatics and comparative religions one could through the years become pretty well educated, irrespective of what might or might not have happened during school and college days.

In trying to get at the reason why our people, especially business men, seem to neglect serious reading—both the variety undertaken for pure pleasure and that which stretches the imagination, adds to a cultural knowledge of our world, and makes broad generalizations possible—we must, I think, refer to our national attitude toward Commencement Day. Whether at high school or college, with a preponderant percentage of graduates it is the day when we say "Goodbye" to books.

Throughout our history success has depended more on native ability, ingenuity and energy than on formal training. This accounts for the point of view that the end of school days is the "commencement" of something different not directly related to education. This attitude seemingly survives today among the heads of our great enterprises.

A force tending to sustain this inherited point of view is our great wealth. The income of individuals is so large, relative to other countries, that they can afford indulgence in stimuli that compete with continued reading and self-education after "commencement." I have in mind night clubs, the theater, the increasing volume of intriguing periodicals of strictly ephemeral value, conventions, trips to Atlantic City and Miami, and what-have-you!

With the development of the professions of law, medicine, dentistry, teaching and engineering, and of our advancing technology—there has come a growing recognition of a relation between education for a profession and success in a profession. The American College of Surgeons, for instance, had the wisdom to put into its first code of ethics a statement that laziness is unprofessional on the part of a surgeon. In view of all there is to read and to know about surgery, a lazy man cannot possibly render the best service.

As our wealth has grown there has come a growing recognition of the relation between education and social status. But there has not been a corresponding growth of a relation between education and success in business, although this is increasing, as is evidenced by the increase of schools of business. Business men seemingly evince less interest in reading than is common among professional classes.

As to reading, Samuel Rea said:

"The business man must never neglect the books which bring us close to great minds, and especially biography and travel, which give us an insight into the lives of successful men and heighten the imagination and increase knowledge of other countries. If neglected by the young business man, he will find him-

self lacking in culture, vision and balance of life. His sympathies will be narrow and selfish." And then he adds, "He must stand for the best things in life and use his service, influence and money to advance them. The world gets nowhere with stand-patters or indifferent people." [3]

Baldwin too was not only an omnivorous reader himself but always placed books at the disposal of those railroad employees who served under him. Few men in any walk of life can give testimony such as this found in a letter from Baldwin to a friend:

"You wrote that you have been indulging freely in Emerson. I myself pick up one of his books every day or two and find that nothing takes his place. I keep his essays 'Society and Solitude' and 'Conduct of Life' on my desk here. I have just read 'Marius' again. * * * The little time I have to read I devote to those books which I have read before."

The virtue in reading for business men seems to lie in the fact that through it new places are visited, new people are met and new ideas are more or less pleasantly thrown on the screen and one's own problems are illuminated by being given status in a somewhat larger world. It is an extension of the commonly accepted idea that any working man, no matter how seemingly unimportant his task, is the better for knowing how it fits in with and is essential to the whole purpose of the enterprise.

ON HOBBIES.

The influence of hobbies appears to be somewhat akin to that of reading. No matter how seemingly trivial the hobby may be, if it tends to keep those directing an enterprise out of grooves or affords surcease from the daily grind, it has merit and may breed power. Naturally, some hobbies have greater influence—personal and social—than others. Sidney Z. Mitchell, president of Electric Bond and Share, was No. 1 man in the flowering era of the great electrical industry. His mind seemed to be so completely occupied with dreams for large-scale electrical development at home and abroad, and the hours per day he devoted to making them come true were so long that I was led to ask a mutual friend if he had any pastimes or hobbies. I was informed that Mitchell probably knew more about blackberries and blackberry bushes than any man in the world. Personally, I do not feel that blackberry culture could greatly stir me. But we cannot be too sure until we have actually encountered the problems and seen where they lead. During the occupancy of Malmaison by the Empress Josephine there were 150 varieties of roses in the garden. When Amos Tuck, who endowed the School of Business Administration at Dartmouth, undertook after World War I to replace them the quest led all over the world and opened unexpected and diverting vistas.

[3] From "Career of Samuel Rea, Ninth President of the Pennsylvania Railroad," by E. Clarke Fowler, published by P.R.R., October, 1925.

Among hobbies, collecting has its devotees. My friend, Henry P. Kendall, a specially able business executive and a leading exponent of Scientific Management, has textile mills both in New England and in South Carolina. So, he eases business burdens in his capacity as a dyed-in-the-wool New Englander by collecting everything which has to do with whaling and its history; and by collecting everything he can find bearing on the history of South Carolina—a subject in which his interest has been aroused by his more recent association with South Carolinians. All such interests and activities lead to meeting new people. The world, and especially our own world, seems larger and more interdependent.

Travel is for some a master diversion—especially when it is so planned as to force the traveler into new and strange ways. Judson Deland, a distinguished physicians' physician of this city, made a practice through a long life of spending his summers in distant countries—China, the Sahara and the far North—where even living was in some respects difficult. For the time of his outing the hour-after-hour, day-to-day stress of a busy Rittenhouse Square office was blotted out completely. Bally is a large-scale shoe manufacturing concern in Switzerland; 95 out of every 100 pairs of shoes worn by the Swiss are made by Bally. Some years ago I was asked by the head of this concern to plan a ten-day trip in this country for a group of the firm's higher executives with the injunction to keep them away from anything reminiscent of shoes. We were told that a different group had been sent the year before on the firm's time and at the firm's expense to the Argentine. Bally followed this custom simply to keep his leading men alive and in touch with the times and the firm's opportunities.

Several years ago the American Society of Mechanical Engineers gave its first hobby show in connection with its annual convention. From 20,000 members there came a great variety of exhibits. Various forms of art expression led the list. From an Honorary Member, a distinguished French engineer, came a collection of heads dexterously carved out of nuts—some of them beautiful, others grotesque. It is interesting to speculate just what direction would be given to a hobby show put on by the National Manufacturers Association or by the Philadelphia Chamber of Commerce or by the Northeast Business Men's Association.

Many, many business men—some of them right here in our own city—find diversion in various types of social service. The late Samuel Fleisher, a Philadelphia business man, in establishing the art center on Catherine Street made it possible for people of all ages and from all economic levels to express themselves in painting and sculpture amid beautiful and inspiring surroundings. It would be difficult to list, and doubtless impossible even to know about all the activities of Samuel S. Fels that lie entirely outside his business—some undertaken

for his personal amusement or edification and others to help in some way his fellow-man.

In his devotion to social services not directly called for by his bread-winning, William H. Baldwin, Jr. certainly picked some hard ones—building libraries as antidotes to saloons, cleaning up New York City's tenements in their worst days and the espousal of the cause of racial minorities, especially the negro.

Business men who have undertaken this kind of work come to realize that the solution—even a partial solution—of a social problem, or even its study, is a broadening process that inevitably makes for a more enlightened outlook on the business world.

ON ONE'S ATTITUDE TOWARD GOVERNMENT.

One of the finest business men it has been my good fortune to meet—the then head of one of Philadelphia's best banks—on one occasion expressed the opinion that if we (doubtless meaning the public) could put the nation's politicians in a boat and send them out to sea and drown them, we should be considerably better off. When returning to Philadelphia from Washington—perhaps ten years ago—I happened to be at a table in the dining car with a fine-appearing Boston business man who had, as it developed, just been asked to take a post in the Treasury. Seeking my counsel, he modestly confided to me that he felt fully competent for the proposed assignment. But, it was clear that he felt that he would be compromising with firmly held moral scruples to work for the government. I am sure that neither of these remarks had any basis in the prejudices normal to partisan politics. They grew out of a sense of superiority to any and all government, a lack of understanding of the field and function of government and, what is more important as bearing on my thesis, they signified an attitude of complete detachment from government. Of course, business men are not the only Americans who seek to disassociate themselves from the political life of their country. For instance, I think it has been quite common for college professors to advise their students to avoid politics on the ground that it is demoralizing, not to use an uglier word. Again, in a recent publication [4] of an important labor union it is said, "To the average American, politicians are crooks." But to the credit of the labor union, after some explanatory verbiage the booklet says, "Let's quit blaming the politicians and face the responsibility of full citizenship."

If our nation is to continue to fulfill its destiny, the leadership will not in the long run remain in the hands of those who hold themselves aloof from the government—Federal, State and local—the structure by which the social and economic life of the people is supported. The

[4] "Political Primer for all Americans," C.I.O., Washington, D. C.

ivory tower is as much out of place in the life of the business man as it has come to be deprecated in the life of scientists. Both business men and scientists will profit by a considered association with the whole life of our people—including the seamless web of government and politics.

There is nothing here which need involve anyone in endorsement of the principles and practices of government with which he is not in sympathy. In our families, in our churches, in our lodges and in our business associations only a Mr. Milquetoast would be in 100 per cent. agreement at all times and as to all matters. But because of disagreements we do not hold ourself aloof and think of these organizations as things apart. Rather we stay with them and seek through our influence in due season to effect what seem to us to be desirable changes.

We Americans cannot remain indifferent to the generally admitted low level of our present-day political life as it is encountered in practically every community in the land. Only as we do something about it are we entitled to the respect of our people and thereby put ourselves in a position to exert a commanding influence. At a time when in Russia those who graft against the State are shot, we in this country cannot afford to continue to smile blandly and wink a lazy eye at conditions with which we would vehemently object to have placed at our individual door. To say that political behavior in this country has always been a bit illicit is begging the question because world conditions are changing. Leaving ethics and morals quite to one side, we may not for long be able to pay the price of either casual or crooked government.

So I hear you ask: Conceding all possible about the necessity for putting the nation's political house in order, what is there except to vote that the individual citizen or business man can do about it? That is a tough question to which perhaps there can be made no convincing answer. But it does emphasize the necessity for building up one's imagination by reading and other practices and so raising one's sights and mental resiliency and optimism to the end that this and other tough problems which confront every individual from time to time can be dealt with in the most constructive manner.

ON LABOR POLICY.

To have a fixed labor policy seems to be most important whether the policy be liberal or conservative. Settled policies about anything often proved as much a hindrance as a help in the days of rugged individualism—the individualism which spanned the nation with railroads, opened the mines, cut down the forests and began the accumulation of our great wealth. Each emergency as it arose was handled with a strong hand on its merits as interpreted by the relatively few in authority. Labor trouble was managed in rough-and-ready fashion with

decisions going one way today and another way tomorrow as seemed expedient to those in charge. These techniques have been largely obsoleted through the assumption by Government of an increasing solicitude for the workers expressed in many ways, as for instance through the regulation of public services, workmen's compensation, unemployment legislation, the limitation of immigration, and legislation protecting labor unions. In other words, the determination of labor policy and the settlement of labor disputes to an increasing extent result from the collective action of numerous agencies and individuals. The facts being somewhat similar in two given controversial situations, there appears to be less and less variation in the final outcome. Certainly our present-day type of rugged individualist finds a narrowing area in which to effect his likes and dislikes.

Under recent legislation collective bargaining has become the law of the land. This means that when the issue is raised an employer is required to negotiate as to hours, wages and working conditions, with representatives of his grouped employees, rather than with individual employees.

Collective bargaining may be an unfortunate term but in the public mind it has come to stand for the only door leading to coöperation between the management and the workers. The dictionary describes it as "negotiation for the settlement of the terms (for example, as to wages) of a labor contract between an employer, or a group of employers, on one side and an organized body of workers on the other." This represents, it seems to me, only the bare bones of collective bargaining and by far its less promising aspect. While even a crude contract may be the only mechanism that can usher in coöperation where conflict has been the rule, a written contract, however detailed, will in the long run prove to be as inadequate an instrument either for expressing or for developing human relations as the long-recognized "Love, Honor and Obey" marriage contract can be looked upon as a satisfactory basis for the marital relationship. Of course, if the relationship between a group of organized workers and their employer is looked upon as without the possibility of improvement or growth, a contract may at least afford the basis for the adjustment of alleged grievances.

Labor unionism is much more widely accepted in Great Britain and in the Scandinavian countries than with us. Notwithstanding this, the leadership of the American labor movement is far more production-conscious than that to be found in any foreign country, and production is the objective of industry. If we play our cards right, we can look forward to the establishment of a constructive relationship between capital and labor that would have seemed quite chimerical a few years ago. The success of the labor-management committees during the

present war proves this. Further, it can be shown that this development will exert a profound and beneficial effect on the political front.

Labor relations in a given plant never remain static. They either advance or retrograde. This leads to a consideration of what causes labor relations to improve. Possibly of dominant importance is the attitude on the part of the employer which results in giving the plant the status of a junior educational institution where everybody from the top down is looked upon as "on the march" to something better as a result of "learning." As Walter Dietz [5] expresses it, "We have had in industry an aristocracy of skill. An aristocracy of learning will carry us much further." Even skill can become static. Therefore, whether in a profession such as surgery, or among experienced industrial managers, or among skilled workmen, too much dependence on the knowledge already in hand is likely to prove unavailing in competition with those who are learning new skills and acquiring new outlooks. This applies equally to nations, to industrial enterprises and to individuals whether their posts be high or low.

If what goes under the name of labor relations consists in unionization and nothing more, the result is pretty sure to be disappointing. The solution seems to lie in making unionization only one and not necessarily the most fundamental influence in bringing about the peace and progress on which a constantly increasing output depends.

ON THE ART OF MAKING DECISIONS.

I suggest a fundamental revision of the techniques used in reaching decisions. The process should be considered as one inviting continuing development. When serving under the gracious tutelage of Mayor Blankenburg I became acquainted with the Quaker method of reaching decisions by taking what they call "the sense of the meeting" as contrasted with voting. It represents a wide departure from rugged individualism. It has proved so satisfactory in practice in the intervening years that I do not recall a single instance of casting a vote or of even being present when the voting method was used. The adoption of this practice generally in the affairs of men would make a new world.

It will be admitted that we need a greater degree of democracy both in government and in industry if they are to serve populations desiring to lead democratic lives, as contrasted with lives some few of them privileged and the remainder unprivileged in varying degree. Note in this connection the increasing tendency toward the overestimation of the top man in all organizations, whether it be the President of the Republic, the general manager of almost any industrial plant or the foreman on a road gang. Over-rating our leaders not only burdens

[5] An officer of the Western Electric Co., and now connected with the Training within Industry Branch of the War Manpower Commission.

them but perhaps, of even greater importance, detracts from the dignity and status of everybody below. The theory seems to be that there is in every organization, in the U. S. Government or in General Motors for instance—I quote—"a supreme coördinating authority (which) operates throughout the whole structure of the organized body." This is nonsense. There are, of course, in any organization dominant and lesser directing functionaries as distinguished from persons with arbitrary powers. But authority—even policy—operates throughout an organization as does water flowing from springs originating at many points located at different levels.

Except on rare occasions industry operates under "The Illusion of Final Authority"—not recognizing, as the late Mary P. Follett has pointed out, that authority, as contrasted with command in military parlance, must be functional and that functional authority is but the counterpart of a very definite functional responsibility. This capacity is developed by encouraging in every one the maximum of appropriate responsibility. *Knowing how* thus becomes the essence of authority. Under modern democratic organization authority should stream up from those who command the local facts quite as much as down from those who, because of position, are compelled to make final and inclusive decisions—decisions in almost all cases dictated solely by the facts when they have been competently assembled. "An executive decision," be it remembered, "is only a moment in a process. The growth of a decision, the accumulation of authority, not the final step is what we most need to study." The leader should constantly be at pains to minimize his own job in order to emphasize the importance of others—especially of those in the organization whom he outranks.

We often hear it said that the top man in an organization should not have anything to do, that if he is the man for the job he should surround himself with good people and let them make the decisions or do the work, however you view the task. If there is even a modicum of truth in the principle, it is equally applicable to the boss's chief assistants and so on down the line. In other words, we are wise to let the bottom-most group decide everything they can. What cannot be decided at the machine should be decided in the shop. Only when the machine group and the shop group are unable to reach decisions should the matter go higher. This is the opposite of the "emperor theory" of running a business.

The Quakers—and I quote:

> "by a combination of free discussion and quiet thinking, try to develop a group willingness to accept unanimously what appears to be the balanced judgment of the majority or of the best-informed. * * * When an agreement is virtually reached on the best course to pursue, the leader will sum up the results in words which he takes to be the 'sense of the meeting,' or consensus of opinion. Those who at an earlier stage might have raised serious objections

often refrain from unduly pressing their opinion when the judgment of the meeting inclines to some other view. Should their ideas be such that the group cannot unite on a decision, the old policy remains unchanged * * * and the subject is dropped for the time being to allow more careful deliberation." [6]

Back of these Friendly techniques [7] there is something that transcends organization and which on occasion baffles pleaders, be they engineers, business men or workers. May I illustrate? In August 1941 a group meeting in a mid-city Philadelphia office were trying to settle a troublesome strike. All interests were represented. The president of the concern was high in the councils of the Episcopal Church. The discussion having become bitterly deadlocked, he said:

"My partner is a Quaker from Delaware County and I propose that after the manner of Friends we settle down to a period of silence and see if we cannot get some light on these troublesome differences."

After five minutes of a profound silence the meeting broke, the discussion was resumed in a different atmosphere, and in a very short time an agreement satisfactory to all was reached.

To sum up then, were I to be asked in my professional capacity to advise business man *X*, *Y* or *Z* as to the steps to be taken to strengthen himself in our developing world, I would suggest—especially if he were a young man:

1. The continuation of education, not directly related to breadwinning, through the cultivation of reading habits that afford pleasure, widen horizons and stretch and enliven the imagination.
2. Cultivate hobbies to prevent a too intense and narrowing absorption in business, with preference given to those that afford the maximum of diversion and to those that involve association with important social causes.
3. Without necessarily being an office-holder, operate from within the structure of government rather than as an outside observer constantly having in mind to strengthen government so that it may better express the highest ideals of our people.
4. Conduct industrial relations in the thought that whatever may be today's accomplishment it will be more satisfactory tomorrow with the personnel at all levels feeling the constant inspiration through educational influences of doing an ever-better job; and
5. Lead yourself and those associated with you toward decisions based on the ascertainment of all pertinent facts and toward the pleasant accommodation of divergent views into a common understanding under which all can act with self-respect.

[6] Quoted from "The Office Supervisor" by Henry E. Niles and M. C. H. Niles. A more formal description of the process will be found in the Book of Discipline published by the Society of Friends.

[7] For further enlightenment on these techniques see "Selected Readings on the Quaker Method of Conducting Business Meetings."

American men of business more than any other group in our common life are so situated today as to advance the American dream. It is in their power to give new life to democracy, to advance education, to abolish poverty, to solve the riddle of scarcity in the midst of abundance, and to set the world on new heights of well-being. We must have an abiding faith that they will adequately meet these new calls. But if they fail, the torch will be lifted from their hands. By whom we do not know. But we do know that the American dream will go on.

NUTRITIONAL ENGINEERING, II: THE NUTRITIONAL IMPROVEMENT OF LIFE.

BY

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American boys and girls now enter college younger yet taller than were their parents and other predecessors when entering the same colleges around 25 to 30 years previously. This fact is shown consistently by Harvard, Vassar, and the University of Cincinnati data—in fact by all the available records when compared over adequate periods, though the figures of individual years may show occasional slight deviations. Unquestionably there is a general trend to a more expeditious development both physical and mental. According to a news dispatch, Yale has reported that its 1943 entering class was the youngest and tallest of any it had recorded up to that date.

There has been no change in proportions of racial stocks that could explain this improvement on genetic grounds. In fact it is shown in father-and-son comparisons as well as in general averages. The explanation is to be found, not in inheritance in the biological sense, but in what may be called a social inheritance—the increase of scientific knowledge and its use in the betterment of conditions of living.

While economic conditions influence the extent to which individuals or families can apply scientific advances to the improvement of their lives, yet the gains indicated by these college records are not confined to the income groups who are financially able to send their offspring to college. The disturbingly large proportion of American youth rejected, in the national draft of 1940–41 as having "physical defects," seems to have been due chiefly to more delicate methods of diagnosis than had previously been used; for the averages of fuller data indicate that the young men of the total nationwide draft of all economic levels now average about an inch taller and correspondingly better developed than did the draftees of 1917–18 at the same ages.

The fact of better development at a given age in the average of our people is partly due to those environmental factors which are under community control; but largely also to what we individually do for ourselves and our children in the formation of food habits under the guidance of nutritional knowledge. Lately it is becoming increasingly clear that, however important the inherited constitution, there is yet

a great opportunity open to each of us to provide for such a favorable internal environment as shall permit each person's native endowments to develop and function most effectively, so that the individual finds fullest satisfaction in life and at the same time renders service of greatest social value.

Such a nutritional improvement of the individual life can begin at any age; and always the sooner and more wholeheartedly one begins, the greater the benefit one may expect.

Then, also, if one has a part in the guidance of younger lives, one may expect the benefits of better food to be still more apparent, even when one starts from levels already within the normal range.

British experience of the influence of nutritional improvement in the previously acceptedly-adequate diets of children of school age has been very instructive.

Boys in an English boarding school were studied for 4 years by H. C. Corry Mann [1] whose findings were critically reviewed by Dr. Walter Fletcher,[2] a very judicially-minded English physician and member of the British Medical Research Council.

These boys had been and were being fed a dietary "planned with every regard for the welfare" of those who were to receive it, and characterized as meeting the standards of good medical men. Yet when a part of these boys were continued on this same dietary while others received a supplement of milk, or of butter, or of water-cress, those receiving any of these added foods made better gains in both height and weight. The best gains were made by those receiving the extra milk, and of these both Mann and Fletcher explicitly concluded that the supplemental feeding improved the rate of mental as well as physical development.

In Dr. Fletcher's words, while all were healthy and provided with a food supply "medically adjudged to be sufficient for healthy development, the boys were in fact not attaining to the physical and mental growth of which they had the potentiality, and to which they did attain when given an extra ration of milk."

Two other tests which, while not so closely controlled as Mann's, were extended to much larger numbers of children, were the Lanarkshire Experiment and the Milk-in-Schools Scheme. In both these investigations also, the addition of milk to the hitherto acceptedly normal dietaries of school children, rated as healthy, resulted in better growth in both height and weight, a higher order of fitness of condition, greater alertness and bouyancy, and an improvement in the average rate of progress in their studies.

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[1] Mann, H. C. C., "Diets for Boys During the School Age," British Medical Research Council, Special Report Series, No. 105, H. M. S. O., London, 1926.

[2] Fletcher, W. M., "The Urgency of Nutritional Studies," Nutrition Abstracts and Reviews, Vol. 1, pages 353–358, 1931.

In the Lanarkshire Experiment [3] one-half of 20,000 school children were continued on their usual home diets while the other half received extra milk on each school day for 4 months. The results as officially reported and interpreted "demonstrate that the addition of milk to the diet of children [supplementary to the milk and other food consumed by the children in their regular meals at home] has a striking effect in improving physique and general health and increasing mental alertness."

Under the authorization and with the aid of the legislation known as the Milk-in-Schools Scheme, the experimental feeding of extra milk to school children was extended to hundreds of thousands of cases, and officially reported as effecting unquestionable improvement in "the children's physical well-being, zest, and mental alertness" and as constituting a "great social and educational advance." [4]

It is noteworthy that in all three of these investigations of children the nutritional improvement was both physical and mental.

Among adults, dietaries better balanced from the viewpoint of the newer knowledge of nutrition have enabled factory employees to work with higher efficiency and less fatigue, increasing both the quality and quantity of their output with fewer accidents to themselves and their material. Efficiency was also found notably increased in work which involved careful matching of materials.

These are only samples of a large and growing mass of evidence that, even when the starting-point is a dietary apparently adequate and a bodily condition already healthy and efficient, we can build to higher levels of health and efficiency by using the guidance of the new knowledge of nutrition in our habitual choice and use of everyday food.

According to physico-chemical principles that have been universally accepted for many years, one must expect some change—as of concentration levels or equilibrium points, for example—to result when one introduces into any system such active factors as are some of the vitamins and mineral salts when taken into our bodies. But for only a few years and perhaps in still fewer laboratories have there been the means of ascertaining the further facts that permit the scientific formulation of the long-run effects of the introduction into our bodily systems of the widely different amounts and proportions of these active nutritional factors which result from ordinary individual differences of food habit.

For this kind of fact finding, scientific research has now developed the possibility of studying certain long-run problems of human nutrition, partly through experimentation with human beings and partly by the use of rightly selected experimental animals of sufficiently short natural life cycle to make manageable and conclusive an unprecedentedly

[3] Leighton, G., and P. L. McKinlay, "Milk Consumption and the Growth of School Children," H. M. S. O., London, 1930.

[4] Official reports, 1941–42, The London Times, *passim*.

comprehensive type of investigation. Today, the well-controlled laboratory colony of species properly chosen for the particular problem in hand, from which colony experimental animals of the same hereditary and nutritional backgrounds can be drawn at precisely known ages, grouped in strict parallel, and fed the diets to be compared throughout entire lifetimes or even successive generations, in sufficiently large numbers for conclusive statistical analysis of results, constitutes a biochemical instrument-of-precision of a kind which has never been available before.

As in the case of other highly developed new research instruments and also of the physico-chemical principles above mentioned, accurate use and valid interpretation may require a degree of training and experience which cannot be fully set forth here. To some extent we must rest upon a presumption of competence in the scientifically trained and experienced investigator. (Is it because there is a lack of the awe-inspiring in an experimental animal as contrasted with an elaborate physico-chemical device, or because we resent the idea of animals being in any way like us, that the person untrained in these research methods is more apt to indulge an unwarranted skepticism regarding animal experimentation than regarding analytical or physical chemistry?)

Rigorously critical interpretation of statistically convincing findings leaves no reasonable doubt that consistent long-run use of present nutritional knowledge at ordinary levels of food purchasing power, can directly improve human life by expediting growth and development so that the individual gets a more advantageous start, lowering death rates and the incidence of many diseases while increasing positive health and efficiency at all ages, thus inducing both a higher and a longer prime of life. And that the benefits are much more than merely biological becomes very apparent when we reflect upon the fact that it is the shortness of available time that limits our cultural attainments in nearly all directions, and our opportunities for the satisfaction of rendering our highest services.

As pointed out by the late Dr. R. S. Woodward, the first third of a scientific or professional man's life is spent in schooling. Then usually another third is expended in so proving to himself and to others what he can do as to win promotion to his major opportunity. Thus, only the last third of his life remains in which to render his highest service. A count of ages at attainment of major opportunity, by each of about 800 men in science and the related professions, confirmed Woodward's average, while also showing that to a considerable number of individuals full opportunity came considerably earlier or later.

From all these viewpoints, it is greatly to the advantage both of the individual and his value to society that he reach his full capacity earlier and hold it longer, as he can by an intelligent nutritional engineering of his own life processes and life history.

Is this equally true for all kinds of careers?

The same material conditions which make the brain of a healthy body a relatively well protected tissue make it less easy to demonstrate the effect of diet upon mental than upon muscular work. But we have just seen examples in which a more scientific guidance of nutrition resulted in higher mental as well as physical efficiency, even in people who were already healthy and efficient; and the present-day science of nutrition shows that this is logically to be expected.

Our bodies have wonderful self-regulating "mechanisms," yet our food does influence our bodily internal environment. Here the blood is the great mediator and the same blood circulates through every part of the body, carrying the influence of the food (whether for better or for worse) to muscles and brain alike.

There seems little reason to doubt and much reason to believe that, whatever one's work may be, the choice of one's daily food is a very large factor in the ability to work at full efficiency and without undue fatigue.

In May of 1941 the First National Nutrition Conference met at the call of the President of the United States and was addressed by Vice-President Wallace who emphasized three ways in which the newer knowledge of nutrition could be put to work for the improvement of human life. In effect * these were and are:

(1) The complete eradication of nutritional deficiency diseases—"we do not have yellow fever any more in this country: We should not have pellagra."

(2) A great reduction of those infectious diseases like tuberculosis, the incidence of which depends largely upon nutritional status.

(3) To bring within the reach of all our people such supplies of the right kinds of foods as to make it possible for all, who will, to attain the efficiency and enjoyment of "health plus."

Within three years the first part of Wallace's program—the eradication of pellagra, begun some years earlier—had been accomplished over large areas and was well on toward completion for the United States as a whole.

At the same 1941 Conference, Dr. Thomas Parran said:

". . . given the national will to do it, we have the power to build here in America a nation of people more fit, more vigorous, more competent; a nation with better morale, a more united purpose, more toughness of body, and greater strength of mind than the world has ever seen. This total result can be accomplished only by putting to work all of the scientific knowledge we have for the nutrition of all of

* The present form of this statement is that first used by the author in a lecture at the University of Maine and reproduced in and from his "Science of Nutrition" (Columbia University Press: New York: 1943).

our people . . . great assets in food production, distribution, education, social awareness, and patriotism can be canalized, through science, toward our goal of nutrition to lift our level of achievement."

It is, of course, self-evident that in wartime the nation awakes to the importance of having all its people so well nourished as to be able to put forth their highest possible efficiency. This requires that all be better nourished than some of the people were in peacetime even in this country with its great wealth of resources for food production. Possibly it may not seem equally self-evident, but it is undoubtedly true that we can share food generously with our Allies and the liberated victims of the war and at the same time have better nutrition at home than we had before the war.

That all of us shall be excellently nourished does not require that we shall have all we might desire to eat of every kind of food. Some foods are inherently expensive of resources to produce. Fortunately, these are not the foods of which our low-income families need larger supplies for good health.

Obviously, different dietary deficiencies may occasionally predominate at different times and places; but it is very significant that the scientific researches of McCollum of Johns Hopkins, of the late Dr. Mary S. Rose, of Drs. Stiebeling and Phipard of the Department of Agriculture, and others, have consistently indicated that American food habits, at all economic levels, are most commonly such as are best improved by increasing the proportion of fruits, vegetables, and milk in the dietary.

In the Foreword of the Department of Agriculture Yearbook for 1939, the then Secretary Henry A. Wallace wrote: "Fifty per cent. of the people of the United States do not get enough in the way of dairy products, fruits and vegetables to enable them to enjoy full vigor and health." And later in the same Yearbook we read in Gove Hambidge's summary: "There is nothing mysterious about the practical application of modern knowledge of nutrition. Leaving out all the details, it says simply that the majority of people need more milk and milk products, eggs, and certain fruits and vegetables than they now get."

Fortunately, the majority of people instinctively eat to about their total food calorie need—otherwise there would be more overweights and underweights than there are now. So when we follow this advice to take more fruits, vegetables, and milk, we are in position to spare more of our supplies of meats and fats for war demands. Of these latter foods, our previous levels of average consumption had been so high that to hold them down by rationing has been entirely consistent with our being excellently nourished. And this situation has been rendered safer for our low income fellow citizens, both by the rationing of meats and fats to equalize consumption and by the increased purchasing power of the large majority of wage-earners' families.

A striking aspect of the nutritional improvement of life is that, with food habits guided by present-day knowledge, full adult capacity and efficiency can be reached at an earlier and held till a later age in the same individual.

This means both higher attainment and the holding of one's highest capacity for service and for enjoyment of life over a longer time.

Because it had been regarded as established that "longevity depends on heredity," even scientifically trained people have been (perhaps still are) a little slow to assimilate the now fully demonstrated fact that both heredity and nutrition are major factors in determining the length of normal lives.

The extra years which the science of nutrition offers, whether these be estimated at seven or ten or more or less, are not to be thought of as added to old age. Rather, they are inserted at the prime (in any life that was not begun too soon to get the full benefit of the newer knowledge). In social-economic terms this means a continuation of the current increase in adult life expectation, and with a *smaller* percentage of years of dependency.

We need not speculate as to whether any individual lives in the future will thereby be rendered superior to the best lives of the past. No one doubts that there have been some born geniuses; and no one expects to be able to produce geniuses to order.

What we can and do expect is that, as the new knowledge of nutrition is more generally understood and followed, a greatly increased proportion of people will build their own and their children's lives to those higher levels of health and enjoyment and social usefulness which have hitherto been the privilege of only the most fortunate few.

Correspondingly we may expect both individual and social enrichment of human life.

Dr. John C. Merriam has pointed out how great is the importance of the length of individual lives to the full social use of the knowledge and institutions which mankind has built. And, from the viewpoint of the individual's enjoyment of life, it is now clear that habitual use of the guidance of the science of nutrition can so increase the efficiency and extent of the fully productive years as greatly to improve the prospect of attaining to one's ideals and objectives, whatever these may be.

Thus, as each of us decides his food habits, he practices (whether consciously or not) his individual sort of nutritional engineering of his own life processes, and thus of his career.

Also, each of us as citizen of a democratic country shares the responsibility for a public kind of nutritional engineering which has to do with the problem of how best to use, for human well-being, our national—and even international—food supplies and resources for food production. In part, these are governmental problems, yet the policies

and decisions of our government rest upon public opinion in the forming of which we each have a share; and in food matters public opinion is very tangibly exercised as consumer demand. Thus, the individual and the public aspects of nutritional engineering interact.

The importance of national and international food policies based on the modern knowledge of nutrition was recognized by the priority given to food in the first gathering of representatives of the United Nations. This meeting, held May–June 1943, was named the United Nations Conference on Food and Agriculture. Its official Declaration, somewhat abridged to save space but with no change in the parts with which we are here concerned, reads as follows:

"This Conference . . . declares its belief that the goal of freedom from want of food, suitable and adequate for the health and strength of all peoples, can be achieved.

"1. The first task is to complete the winning of the war and to deliver millions of people from tyranny and from hunger. During the period of critical shortage in the aftermath of war, freedom from hunger can be achieved only by urgent and concerted efforts to economize consumption, to increase supplies and distribute them to the best advantage.

"2. Thereafter we must equally concert our efforts to win and maintain freedom from fear and freedom from want. . . .

"3. There has never been enough food for the health of all people. This is justified neither by ignorance nor by the harshness of nature. . . .

"4. The first cause of hunger and malnutrition is poverty. . . . There must be an expansion of the whole world economy to provide the purchasing power sufficient to maintain an adequate diet for all. With full employment in all countries, enlarged industrial production, the absence of exploitation, an increasing flow of trade within and between countries, an orderly management of domestic and international investment and currencies, and sustained internal and international economic equilibrium, the food which is produced can be made available to all people.

"5. The primary responsibility lies with each nation for seeing that its own people have the food needed for life and health; steps to this end are for national determination. But each nation can fully achieve its goal only if all work together.

"6. We commend to our respective governments and authorities the study and adoption of the findings and recommendations of this Conference and urge the early concerted discussion of the related problems falling outside the scope of this Conference.

"7. The first steps toward freedom from want of food must not await the final solution of all other problems. Each advance made in one field will strengthen and quicken advance in all others."

We, the people of the United States, are now in the midst of the first crop year planned since the formulation of the Declaration just cited. Our immediate national nutrition policy is manifested in the Food Production Goals for 1944 recommended to our farmers by the Department of Agriculture and War Food Administration. These goals have also the background of nearly three years since Pearl Harbor, nearly four years of Lend-Lease, and about eight years experience by this country in consciously planning its food production to a considerable extent in terms of our national nutritional needs.

Full attainment of the benefits sought through these goals requires conscious adjustment in the consumption as well as the production of food. In part, the needed adjustment of our food consumption habits is made a matter of nationwide rationing for the duration of the war emergency, while for fullest effectiveness in our utilization of food as a weapon of war and a pillar of peace we need voluntary individual cooperation as well.

It is most fortunate for us individually and for our nation, that in sharing liberally the foods that are most practicable for shipment overseas, we can shift the emphasis of our home consumption to foods more bulky, watery and perishable which yet are more effective in the better balancing of our common food habits of the past. We have good reasons to believe that the gains already registered in our nutritional well-being are but a beginning.

By this we do not mean to imply an unlimited accentuation of physical growth and bodily size. More probably, the service of nutritional knowledge to national physique will be in bringing a larger proportion of the people to the bodily development and carriage hitherto characteristic of the economically favored families; while at all economic levels we may expect such improvements of internal environment * as shall make people more resistant to disease and to ageing, better adapted to mental work, and able to do their best through a longer term of years. Thus, as Dr. McLester put it in his presidential address to the American Medical Association, science promises to those peoples who will use the newer knowledge of nutrition in the engineering of their lives, "greater vigor, increased longevity, and a higher level of cultural attainment."

* Undoubtedly we still have many cases of undetected malnutrition. See, for example, Kruse, H. D., and others 1943, "Inadequate Diets and Nutritional Deficiencies in the United States," Bulletin of the National Research Council, No. 109.

Failure of Spherical Hydrogen Storage Tank.—A. L. BROWN AND J. B. SMITH. (*Mechanical Engineering*, Vol. 66, No. 6.) On Feb. 16, 1943, a spherical hydrogen storage tank, 38.5 ft. in diameter, located beside the gas generator building, General Electric Company, Schnectady, N. Y. failed structurally with explosive violence. The sphere was made of welded steel plate, and materials, design, and erection were in accordance with the ASME Code. The tank was designed for a working pressure of 50 psi and contained hydrogen at about this pressure. It was protected against normal excess pressure by two 2 in. relief valves. One of the valves, not seriously damaged by the accident, was tested with air and found to open properly at from 53 to 58 psi gauge.

Immediately preceding the accident there was a 36 hour period of subzero temperature, following which the thermometer rose about 27° F. in seven hours and was about 10° F. when failure occurred. At this time the sun was shining on a point about diametrically opposite a manhole about 20 inches inside diameter.

The sphere plates of steel 0.66 inches thick were arranged according to the zones of the earth—Arctic, North Temperate, Torrid, South Temperate, and Antarctic.

The plates were shop formed cold and were erected in the field by the builder. The generally excellent quality of the welding is demonstrated by the fact that only a few feet of fracture followed the many feet of welded seams. It is significant also that the fractures did not involve, except in a minor way, the support leg attachments where there are concentrated stresses due to the loads from the dead weight of the sphere.

The sphere burst into about twenty fragments. Each piece was surveyed, and using welds as reference lines, all fractures were plotted to scale on a model sphere 15 inches in diameter. An inspection was also made of the characteristic "herringbone" markings on fracture edges, indicative of the direction of tearing of the total of 650 ft. of fracture. The final resting place of the fragments was also noted and from all this evidence a reconstruction of the progress of the failure was made.

At first, appearances indicated that an internal-combusting explosion had occurred, but this theory was not supported by the evidence. It was concluded that the structural failure resulted from the coincidence of a number of factors, each unfavorable to the stability of the sphere, which, if considered singly, would probably not have seemed serious. These factors included (1) a stress level, from the normal internal hydrogen pressure that was higher at the manhole neck owing to the stress raising effect of the 20 inch opening, (2) residual stresses in the same location due to shrinkage of weld metal deposited in the joint between the manhole neck and the sphere plate, (3) the greatly increased brittleness, under the low temperature conditions of the welded plate used, (4) the probable occurrence of some type of shock imparted to any part of the sphere, such as the formation of a crack as a result of increasing hydrogen pressure caused by the rapid rise of outdoor temperature.

R. H. O.

ON THE METHOD OF COLLOCATION.

BY

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The term "collocation" is used in connection with approximations to denote the act of assigning a value, usually zero, to the error at given points or stations. The method has been applied to the problem of the approximate determination of characteristic numbers in the following way:[1] suppose that the homogeneous differential equation containing the parameter λ together with homogeneous boundary conditions leads to characteristic numbers $\lambda_1, \lambda_2, \ldots$ for which solutions other than the trivial one, $y = 0$, exist. Let this differential equation be

$$L\{y\} + \lambda m(x)y = 0, \tag{1}$$

where

$$L\{y\} \equiv a_n(x)\frac{d^n}{dx^n} + a_{n-1}(x)\frac{d^{n-1}}{dx^{n-1}} + \cdots + a_1(x)\frac{d}{dx}.$$

Let $y(x)$ be represented by

$$y(x) = \sum_{k=1}^{n} b_k Y_k(x), \tag{2}$$

where the Y's are functions satisfying the boundary conditions and the b's are constants. Substituting (2) into (1) leads to

$$L\{\sum b_k Y_k(x)\} + \lambda m(x) \sum b_k Y_k(x) = \epsilon(x), \tag{3}$$

where $\epsilon(x)$ may be referred to as the error. If $\epsilon(x)$ is made zero at as many points $x_1, x_2, \ldots$ as there are constants b, there results a system of linear homogeneous equations in the b's. The vanishing of the determinant of the coefficients of the b's, a necessary condition for a non-trivial solution, leads to the characteristic equation from which approximations to the λ's may be found. In most cases at least three or four constants must be used to get fair accuracy in the determination of the lowest characteristic number.

In the Galerkin method,[1] the error $\epsilon(x)$ is distributed over the extent of the system by making

$$\int_0^l \epsilon(x) Y_k(x)dx = 0; \qquad k = 1, 2, \cdots n.$$

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This also leads to a system of linear homogeneous equations in the b's from which the characteristic equation and approximations to the λ's may be found. Grammel has proposed a converse to the method of Galerkin by starting from the homogeneous integral equation associated with the problem instead of the differential equation.[2]

The present aim is to propose a method which has certain advantages in many cases over collocation of the differential equation and over Grammel's method. It is a collocation of the integral equation associated with the problem. Let this equation be

$$y(x) = \lambda \int_0^l m(s)G(x, s)y(s)ds, \tag{4}$$

where $G(x, s)$ is the appropriate Green's function.

As before $y(x)$ is assumed to be represented by

$$y(x) = \sum_{k=1}^{n} b_k Y_k(x). \tag{5}$$

However, since $G(x, s)$ satisfies all of the boundary conditions of the problem, less restrictive conditions apply to the Y's. As Grammel points out, the Y's should at least satisfy the geometrical boundary conditions in order to obtain a good result. This will be apparent in the example shown below.

The error $\epsilon(x)$ may be found by substituting (5) into (4) leading to

$$\sum b_k Y_k(x) - \lambda \int_0^l m(s)G(x, s)[\sum b_k Y_k(s)]ds = \epsilon(x). \tag{6}$$

As before $\epsilon(x)$ may be set equal to zero at as many points $x_1, x_2, \ldots$ as there are constants b. Again this leads to a system of linear homogeneous equations in the b's from which the characteristic equation and approximations to the λ's may be found.

In some problems, particularly those which have to do with finding the natural frequencies of vibration of beams, Green's Function need not be found or used since the integral

$$\int_0^l m(s)G(x, s)\,Y_k(s)ds$$

may be interpreted as the deflection of the system under a load of $m(x)\,Y_k(x)$ per unit length and simpler methods may be used to effect its evaluation.

A simple example showing a typical application of the method is that of finding an approximate value for the lowest natural frequency of vibration of a uniform cantilever beam. Let the beam be clamped at $x = 0$ and free at $x = l$. The natural boundary conditions are

$$y(0) = y'(0) = 0,$$
$$y''(l) = y'''(l) = 0.$$

Let y be represented by bx^2, a very simple function satisfying only the geometrical constraints of the problem. As a consequence

$$bx^2 - \lambda mb \int_0^l G(x, s)s^2 ds = \epsilon(x).$$

Interpreting the integral as the deflection of the cantilever beam under a load of intensity x^2 this becomes

$$bx^2 - \frac{\lambda mb}{EI} x^2 \left\{ \frac{l^4}{8} - \frac{l^3 x}{18} + \frac{x^4}{360} \right\} = \epsilon(x).$$

Setting $\epsilon(l) = 0$, it is found that

$$\lambda = 13.85 \frac{EI}{ml^4},$$

where λ is the square of the circular frequency. The exact value is $12.36(EI/ml^4)$. Thus the error in the frequency itself is slightly over 6%.

This error may be considerably reduced by selecting a function which satisfies in addition to the geometrical requirements, the dynamical boundary conditions. For example, if in the preceding problem the function

$$y = b(6x^2 - 4x^3 + x^4) \tag{7}$$

is used, then in addition to the conditions $y(0) = y'(0) = 0$, conditions $y''(1)$ and $y'''(1)$ equal to zero are also satisfied. The length of the beam is now taken as unity to simplify the numerical calculations. From area-moment or other considerations, it may easily be shown that the deflection of the cantilever beam of unit length under a load of intensity x^n is given by

$$y = \frac{x^2}{EI} \left\{ \frac{1}{2(n+2)} - \frac{x}{6(n+1)} + \frac{x^{n+2}}{(n+1)(n+2)(n+3)(n+4)} \right\}, \tag{8}$$

x being measured from the fixed end. With the assumed deflection curve given by eq. (7) and interpreting the integral in eq. (6) in the light of eq. (8), it is a simple calculation to find

$$p^2 = 12.22 \frac{EI}{ml^4}$$

as a result of collocating the error at the free end of the beam. The error in the frequency p is about 0.6 per cent.

It is of interest to compare these results with those obtained through collocation of the differential equation. The error $\epsilon(x)$ in the case of

the vibrating beam of uniform mass is given by

$$\frac{d^4y}{dx^4} - \frac{mp^2}{EI}\,y = \epsilon(x).$$

Representing y by bx^2 evidently leads to no result. On the other hand, representing y by $b(6x^2 - 4x^3 + x^4)$ results in

$$b(24) - \frac{mp^2}{EI}\,b(6x^2 - 4x^3 + x^4) = \epsilon(x),$$

where, as above, the length l of the beam has been taken as unity and is introduced into the final answer from dimensional considerations. The error at the free end of the beam being set equal to zero leads to $p^2 = 8EI/ml^4$, an error of about 19.5 per cent. in the frequency p itself.

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(1) FRAZER, JONES, AND SKAN: "Approximations to Functions and to the Solutions of Differential Equations," Aeronautical Research Committee Reports and Memoranda No. 1799, London, 1937.

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ABSTRACT OF THE TRUE STRESS-STRAIN TENSION TEST—ITS ROLE IN MODERN MATERIALS TESTING.

BY

C. W. MACGREGOR.*

The fundamentals of the true stress-strain tension test are discussed. The application of this form of tension test in revealing the effects of different mechanical and metallurgical conditions on fundamental material properties is dealt with in some detail. The mechanical conditions discussed include the effects of low and elevated temperatures of testing, the velocity of deformation, and the proportions of the test bar. The metallurgical conditions include the influence of heat-treatment, alloying additions, cold-work, over-heating, and directional properties.

The application of the true stress-strain tension test in connection with metal forming processes, notched-beam-impact tests, fatigue tests, notch-effect tests, and combined stress experiments is described.

THE TRUE STRESS-STRAIN TENSION TEST—ITS ROLE IN MODERN MATERIALS TESTING.

PART I.

BY

C. W. MACGREGOR.[1]

I. INTRODUCTION.

Throughout the history of materials testing the tension test has been one of the most common methods used to reveal the physical properties of materials. The procedure for conducting the ordinary form of tension test has been standardized and is specified in detail by the A.S.T.M. Standard Methods of Tension Testing of Metallic Materials (E8–40T).[2] In the ordinary form of test, it is customary to determine the proportional limit, the yield strength, the tensile strength, the per cent elongation and the per cent reduction of area. In case a stress-strain curve is drawn, the stress and the strain are referred to the original dimensions of the specimen.

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[2] A.S.T.M. Standards 1940 Supplement Part I, pp. 453–463.

The conventional method of conducting a tension test just referred to has yielded valuable information and the physical properties thus disclosed have proved useful in design. This is especially true as regards the so-called elastic properties, the proportional limit, the yield strength, and the modulus of elasticity.

It is very desirable, however, to have the tension test reveal more information about the material than is contained in the so-called elastic properties. For example, the test should provide a control as regards the state of heat-treatment, cold-work, directionality, etc. It should be possible to relate it to other forms of tests such as combined stress tests of various kinds, bending tests, fatigue tests, impact tests and others. In addition, it would be very useful if the tension test could be related to and throw light upon the various metal forming processes such a deep drawing, wire drawing, rolling and extrusion of metals. Further, the tension test should be of assistance in disclosing those laws governing plastic flow and fracture in engineering materials.

Experience through the years has demonstrated, however, that the tension test, in its conventional form, is of very little assistance on most of these problems. That this should be the case does not seem at all surprising when one considers the essential empirical nature of the test. This was originally pointed out by P. Ludwik.[3] As soon as yielding commences, the area of cross-section of the test bar begins to diminish and as the test proceeds the load divided by the original area, as customarily used, becomes less and less exact. The stresses so obtained are entirely fictitious and are greatly in error near fracture. The strain and reduction of area definitions used were inherited from the mathematical theory of elasticity where the deformations are assumed to be small. This leads to considerable ambiguity as regards the choice of the proper reference dimension. In addition, when local necking starts after the maximum load has been reached, the strain variation along a 2-inch gage length is very great for most metals. This means that the strain computed over such a gage length near fracture has little physical significance.

In view of these facts, about ten years ago the author decided to investigate the tension test in some detail and to attempt to place it on a more rational foundation. A fairly extensive research investigation was started at that time under the author's direction at the Massachusetts Institute of Technology. This investigation has been carried out more or less continuously since then and is still underway at the present writing. A number of papers to be referred to later have been published reporting from time to time the progress on various individual phases of the study. The objects of the present paper are to attempt to summarize and to correlate the various individual phases

[3] P. Ludwik, "Elemente der technologischen Mechanik," Julius Springer, Berlin (1909).

of the investigations to date and at the same time to present various new and unpublished results.

The paper is divided into two parts. Part I will discuss the true strain values used in the tension test, the different methods available for determining true stress-strain curves, the true stress-strain curves resulting from the use of these methods, the ductility values based on true strain, and the effects of various mechanical conditions on true stress and strain values such as, high and low testing temperatures, the velocity of testing, and the proportions of the test bar.

In Part II, the effects of different metallurgical conditions on the true stress-strain properties will be described, such as the effects of heat-treatment, alloying additions, cold-work, overheating, and directional properties. In addition, the role of this form of tension test in modern materials testing will be discussed, especially as to its use in connection with the metal forming processes, notched-beam impact tests, fatigue tests, notch-effect tests, and combined stress tests.

II. TRUE STRAIN VALUES.[4]

Let us consider a uniform test bar having an original gage length L_0 and a cross-sectional area A_0 which is subjected to a uniaxial tensile load of magnitude P. The symbols used are listed in Table I. According to our common strain and reduction of area definitions adopted from purely elastic considerations, it follows that

$$\epsilon_0 = \frac{\Delta L_0}{L_0} \quad \text{and} \quad q_0 = \frac{\Delta A_0}{A_0}, \tag{1}$$

where ϵ_0 and q_0 are the ordinary axial strain and reduction of area respectively. In this case, if the values of ΔL_0 and ΔA_0 are very small as compared to L_0 and A_0, no ambiguity results. On the other hand, if ΔL_0 and ΔA_0 are large and no background of elastic considerations existed, the final length and area might have been used as reference dimensions. In fact, the latter definition has been used in the testing of materials. Our intuitive conception of strain as a change in length referred to the length from which that change is produced directs us to the conclusion that for large deformations, the strain definition is more likely a summation process.

If we now consider a succession of loads ΔP_i being applied to the bar, there will be produced a series of small increments of gage length ΔL_i and decrements of area ΔA_i. If each value of ΔL_i and ΔA_i is

[4] C. W. MacGregor, "Relations Between Stress and Reduction in Area for Tensile Tests of Metals," Tech. Pub. 805, Metals Technology, April, 1937; also "Differential Area Relations in the Plastic State for Uniaxial Stress," Stephen Timoshenko 60th Anniversary Volume, The Macmillan Co., New York, 1939; "The Tension Test," *Proc. Am. Soc. Test. Materials*, vol. 40, pp. 508–534, 1940. (The latter paper contains an extensive bibliography on the subject and therefore will not be duplicated here.)

TABLE I.

Notation.

P	—Axial tensile force (Lbs.).
L_0	—Original gage length (In.).
A_0	—Original cross-sectional area (In.²).
L	—Instantaneous gage length (In.).
A	—Instantaneous area of cross section (In.²).
S	—True stress (Lbs./In.²).
ϵ_0	—Ordinary axial strain $\frac{\Delta L_0}{L_0}$.
q_0	—Ordinary reduction of area $\frac{\Delta A_0}{A_0}$.
ϵ	—True axial strain $\log_e \frac{L}{L_0}$.
q'	—True reduction of area $\log_e \frac{A_0}{A}$.
d_0	—Original diameter for round bar (In.).
d	—Instantaneous diameter for round bar (In.).
h	—Instantaneous width of flat bar at center of longest side (In.).
c	—Instantaneous thickness of flat bar parallel to short side at center of bar (In.).
b	—Instantaneous thickness of flat bar parallel to short side at the ends of the cross section (In.).
$\epsilon_u = q'_u$	—True uniform axial strain $\log_e \frac{A_0}{A_u}$.
$\epsilon_n = q'_n$	—True local necking axial strain $\log_e \frac{A_u}{A_b}$.
$\epsilon_b = q'_b$	—True fracture axial strain $\log_e \frac{A_0}{A_b}$.
A_u	—Actual area of cross section at the maximum load (In.²).
A_b	—Actual area of cross section at fracture (In.²).
$\frac{\partial S}{\partial \epsilon}$	—Minimum modulus of strain-hardening (Lbs./In.²).
S_i	—Intercept obtained by extrapolating linear portion of true stress-strain curve to stress axis (zero strain axis) (Lbs./In.²).
b_0	—Original width of flat test bar (In.).
t_0	—Original thickness of flat test bar (In.).
S_u	—True axial stress at the maximum load (Lbs./In.²).
S_b	—Average true axial stress at fracture (Lbs./In.²).
τ_n	—Octahedral shearing stress (Lbs./In.²).
γ_n	—Octahedral shearing strain.
S_1, S_2, S_3	—Principal stresses (Lbs./In.²).
ϵ_1, ϵ_2, ϵ_3	—Principal strains.

referred to the length or area from which it is produced, there results

$$P = \sum_{i=0}^{n} \Delta P_i, \qquad \epsilon = \sum_{i=0}^{n} \frac{\Delta L_i}{L_i}, \qquad q' = -\sum_{i=0}^{n} \frac{\Delta A_i}{A_i}, \tag{2}$$

where P, ϵ, and q' are the final axial load, the true strain and the true reduction of area, respectively. If L and A represent the final gage length and cross-sectional area of the specimen, we obtain by passing

to the limit as $n \to \infty$ and ΔL_i and ΔA_i approach zero,

$$\epsilon = \int_{L_0}^{L} \frac{dL}{L} = \log_e \frac{L}{L_0}; \qquad q' = -\int_{A_0}^{A} \frac{dA}{A} = \log_e \frac{A_0}{A}. \tag{3}$$

Since for most engineering ductile metals the volume remains constant, it follows from equation (3) that

$$\epsilon = q', \tag{4}$$

which means that the true axial strain and the true reduction of area are equal in the plastic range.

The true strain and reduction of area can be related to the ordinary strain and reduction of area through equations (1) and (3) and there results

$$\epsilon = q' = \log_e (1 + \epsilon_0) = -\log_e (1 - q_0). \tag{5}$$

Equation (3) also indicates that the areas decrease exponentially with the true strain or if the test was conducted at a constant true strain rate, they decrease exponentially with the time. The expression for q' is thus somewhat analogous to the logarithmic decrement of the amplitudes of vibration for a mass vibrating in one degree of freedom with viscous damping. In the present case q' is essentially the logarithmic decrement of successive values of the areas of cross-section.

An important feature implicit in equations (3) is that they hold also for bars of any cross-section, flat, round, etc. For round bars equations (3) become

$$\epsilon = q' = 2 \log_e \frac{d_0}{d}. \tag{6}$$

This conception of the equality of true axial strain and true reduction of area has led to an improved method of determining true stress-strain curves since they can thus be determined *from simple lateral measurements* only. The difficulties arising from attempts to determine true stress-strain curves from axial strain measurements are at once apparent when one considers that not only would strain gages of very small gage length be necessary due to the tremendous strain variation along the bar during necking after the maximum load, but the pre-location of the strain gage at the point along the bar where local constriction will take place is almost impossible to predict in advance of the test.

III. METHODS OF CONDUCTING TRUE STRESS-STRAIN TENSION TESTS.

Two different methods are available for conducting true stress-strain tension tests of the form described herein. For the sake of brevity, they will be called (1) the multi-load or continuous reading method and (2) the two-load method.[5] In both, the true axial strains are

[5] C. W. MacGregor, "A Two-Load Method of Determining the Average True Stress-Strain Curve in Tension," *Jnl. Applied Mechanics*, vol. 6, A156–158, 1939.

determined through lateral measurements as discussed above. The methods differ in the choice of the positions along the test piece for lateral measurements and in the time at which these measurements are made. Although both methods can be used with test speicmens having cross-sections other than circular as for example for flat test bars, etc., they will be illustrated in the following for round specimens.

Multi-Load Method.

Under the multi-load method, simultaneous readings of the axial load and the minimum diameter are taken throughout the test from initial yielding to fracture. The test may be conducted either on a hydraulic or a beam type testing machine. The continuously indicating hydraulic machine, however, is more convenient.

The minimum diameters can be measured by various means such as with a ball point micrometer, a cathetometer, various types of special lateral strain gages, or with a simple device consisting of a dial gage mounted in a "C" clamp. In most of our experiments, the latter instrument was used. The dial gage is clamped to one side of the "C" clamp with a small knife edge attached to the moving stem of the gage. Another knife edge is attached to the opposite side of the "C" clamp and is adjustable. This provides a rugged instrument which is sufficiently accurate for most purposes. The instrument may be applied to the test bar by hand and the minimum diameter can always be determined by sliding the instrument up and down the specimen during the test.

From these readings, a curve is plotted with the true stress $S = \frac{P}{A}$ as the ordinate and the true strain $\epsilon = q' = 2 \log_e \frac{d_0}{d}$ as the abscissa. The true stress is thus determined by dividing the instantaneous load P by the actual area A existing at the same instant. Fig. 1 shows a typical true stress-strain curve obtained by applying this method to a 0.20 per cent carbon steel in the annealed condition. The test piece had a uniform diameter of 0.505". It will be seen that the curve becomes a straight line from the maximum load point (indicated by a solid triangle) to fracture. This example does not represent an anomaly. We have tested thousands of different specimens of various metals, both ferrous and non-ferrous, heat-treated and not heat-treated, and all specimens have shown a linear characteristic from the maximum load to incipient fracture.

Aside from the fact that a relationship is thus established between true stresses and strains and we are thus dealing with well defined physical quantities as contrasted to the ordinary fictitious stress-strain values, the linear variation of the true stress and strain from the

maximum load to fracture offers several distinct advantages. Among these may be mentioned that (1) actually only 2 points are necessary to establish the curve in this region, thus reducing the number of observations required, (2) a simple analytical relation may be formulated between the ordinary tensile strength and the breaking stress and (3) it makes possible the use of the so-called two-load method to be described shortly.

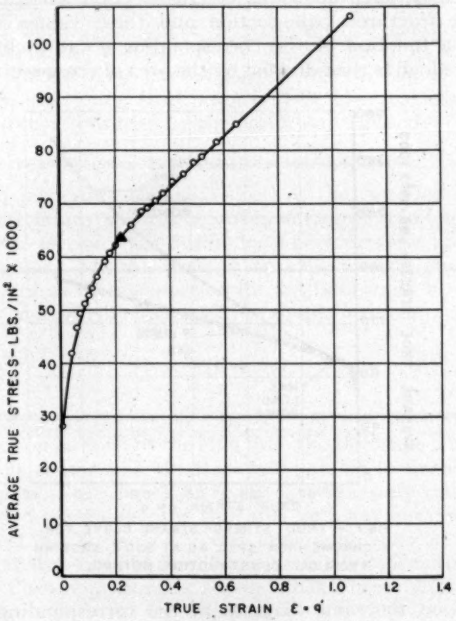

FIG. 1 TRUE STRESS-STRAIN CURVE FOR 20C ANNEALED MILD STEEL.

The experimental technique is indeed simple. Less equipment is necessary to determine the true-stress strain curve than for ordinary stress-strain curves. The time necessary for both is about the same.

Two-Load Method.

The two-load method is applied to testing problems where it is either not possible to take lateral measurements during the test, or difficult and time consuming to do so. Examples of such cases are the tension impact problem, short-time high-temperature tests, etc.

To apply this method, a tapered specimen is used which is scribed by means of a diamond scriber with light transverse scratches at close intervals along the length. The diameters of the bar are then measured at these same positions before the test is started. No strain readings are taken during the test and the only readings recorded are the maximum and fracture loads. The final diameters are re-measured at the same positions after the specimen is broken. The maximum load is then divided by each final area of cross-section along the bar all the way to the fractured cross-section and these values of P_{max}/A are plotted as a function of the corresponding q' at each cross-section. The fracture load is then divided by the area of cross-section at fracture

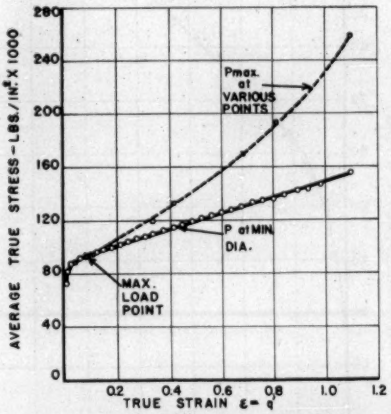

FIG. 2 — TRUE STRESS-STRAIN CURVE FOR CHROME IRON SPEC. 4B AT 950°F SHOWING TWO-LOAD CONSTRUCTION METHOD.

and plotted on the same diagram at the corresponding value of q'. From this latter point a straight line is drawn tangent to the P_{max}/A curve at its point of inflection. It can be readily shown and verified experimentally that the P_{max}/A vs. q' curve represents the true stress-strain curve of the material from initial yielding to the maximum load point, and the straight line drawn tangent to this curve from the fracture point represents the remaining portion of the true stress-strain curve from the maximum load point to fracture. The method is complete in that it determines the true stress-strain curve from incipient yielding to final fracture.

Fig. 2 illustrates the application of the two-load method in determining the true stress-strain curve for Chrome Iron at a testing temper-

ature of 950° F. The test piece was 0.375″ in minimum diameter and had a continuous curved taper of 12″ radius. The dashed curve is the P_{max}/A curve and the solid one is the true stress-strain curve. The dashed curve is essentially merely a construction curve. While it was not at all necessary in using the two-load method to take strain readings during the test, these were taken continuously in this case up to fracture in order to serve as a check on the method. The points obtained are also plotted along the straight line portion of the curve. It is thus seen that once the P_{max}/A curve is established, if a straight line is drawn from the fracture point to the P_{max}/A curve at its point of inflection, this portion of the curve together with the part of the P_{max}/A curve up to the maximum load point will be identical with the true stress-strain curve determined by the multi-load method.

IV. APPLICATION OF METHODS TO FLAT SPECIMENS.

In order to use either the multi-load or the two-load method on flat bars, it is necessary to have a convenient procedure for computing the areas of cross-section since during local necking these areas will not remain rectangular. On the basis of an experimental study,[4] it was shown that the areas of cross-section for flat bars could be determined with sufficient accuracy by means of the simple formula

$$A = \frac{h}{3}(b + 2c), \tag{7}$$

where A, h, c and b are the area of cross-section, the width at the center of the cross-section parallel to the long side, the thickness parallel to the short side at the center, and the thickness parallel to the short side at the ends of the cross-section respectively. Hence, only three measurements are needed to establish the true area for a flat specimen. At the author's suggestion, Formula (7) was later applied to new test data obtained on flat bars of mild steel having various ratios of h/b by F. J. Mehringer.[6] These experiments showed that Formula (7) is accurate to within about 1 per cent for ratios of h/b less than 4, with slightly greater errors for the ratio of $h/b = 6$. With greater ratios than 6, errors of several per cent may be encountered when using this expression and considerable caution needs to be observed. For example when $h/b = 26$, the maximum error in area determination amounted to about 5 per cent. While the error in area determination by the rapid means of equation (7) increases for wider specimens, it should be noted that for ratios of $h/b > 6$ the fracture changes in character from a horizontal tensile fracture to a shearing fracture making an angle of about 25° with the horizontal. The distribution of stress in such wide specimens

[6] F. J. Mehringer, "True Stress-Strain Curves for Flat Steel," B. S. Thesis, Massachusetts Institute of Technology, 1941.

even in the elastic range is probably far from uniform and at the center of the bar during yielding a lateral stress equal to one-half the axial stress is present due to the lateral restraint involved.

By the use of equation (7), or a similar one for ratios of $h/b < 6$, the cross-sectional areas may be determined either for the multi-load method or for the two-load method. In both, it has been found convenient to use a dial gage and "C" clamp similar to that used for the round specimens described earlier except that the knife edges are replaced by ball or conical points. For a large number of specimens of a standard size, a special jig may be designed to accelerate the taking of measurements.

A true stress-strain curve made on a flat bar of fully annealed S.A.E.-1112 steel using the multi-load method is included in Fig. 3.

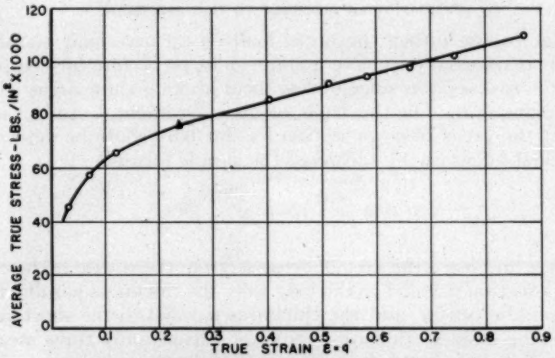

FIG. 3 TRUE STRESS-STRAIN CURVE FOR FLAT BAR OF S.A.E.-1112 STEEL IN THE ANNEALED STATE.

The test bar was of a uniform cross-section $1/2'' \times 3/16''$ with an $8''$ gage length and was prepared according to the A.S.T.M. standards for flat specimens. It will be noticed here that there is also a linear relation between stress and strain above the maximum load point located by the solid triangle. A similar curve for another low carbon steel is shown in Fig. 4. In this case, the test was conducted on a tapered specimen by the two-load procedure. The specimen had a $12''$ radius symmetrical taper on the width. The original cross-section at the bottom of the taper was $1'' \times 0.75''$

V. DUCTILITY.

The quantities most commonly used today to give a measure of ductility are the per cent elongation ϵ_0 in 2 inches and the per cent reduction of area q_0. The great variation of the strain along the axis

of most test pieces near fracture renders the first of these quantities of questionable significance. In addition, even if the specimen remained of uniform cross-section all the way to fracture, ϵ_0 is not a true strain. The value of q_0, while no doubt being a better ductility guide than ϵ_0, does not represent a true reduction of area nor is it conveniently related to a true strain. Both of these quantities are usually specified, however,

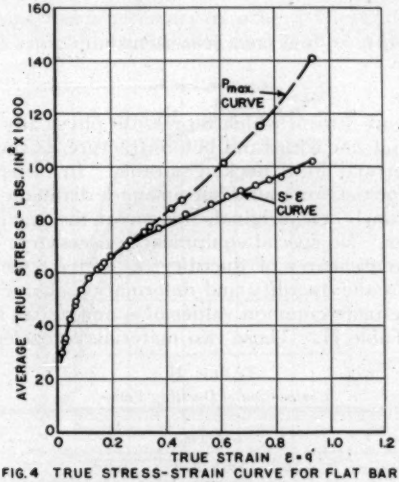

FIG. 4 TRUE STRESS-STRAIN CURVE FOR FLAT BAR OF ANNEALED MILD STEEL BY THE TWO-LOAD METHOD.
CROSS-SECTION - 1 X 0.75 INCHES.
UNIFORM RADIUS TAPER - 12 INCHES

since it is recognized that each gives some information not included in the other.

Proposals have been made at different times to use the uniform elongation ϵ_0 in 2 inches obtained from axial strain measurements, i.e. the elongation from initial yielding to the maximum load, as a measure of ductility. This idea may be formulated from the true strain standpoint in which lateral measurements only are utilized.[4]

The true strain at the maximum load, or the true uniform strain is

$$\epsilon_u = q_u' = \log_e \frac{A_0}{A_u}, \tag{8}$$

where A_0 is the original area and A_u the area at the maximum load.

Similarly, the true local necking strain is

$$\epsilon_n = q_n' = \log_e \frac{A_u}{A_b}, \tag{9}$$

where A_b is the fracture area. The true fracture strain is

$$\epsilon_b = q_b' = \log_e \frac{A_0}{A_b}. \tag{10}$$

From equations (8), (9) and (10), it is seen that

$$\epsilon_b = \epsilon_u + \epsilon_n \tag{11}$$

or the true fracture strain, which represents physically the maximum strain the material can withstand before fracture, is the direct sum of the true uniform and local necking strains. In order to determine these strain quantities for round specimens 3 diameter measurements are necessary; namely, the original, the one at the maximum load and the final diameter. No special equipment is necessary.

That the two measures of ductility, ϵ_u and ϵ_n, yield much more information about the ductility and deformation characteristics of the material than the more common values of ϵ_0 and q_0 can be readily seen by referring to Table II. These two materials are selected merely as

TABLE II.

Comparison of Ductility Values.

Material	ϵ_0 in. 2 in.	q_0	ϵ_u	ϵ_n
Commercially Pure Copper as Received	0.149	0.605	0.0119	0.921
Cold-Drawn Brass 65–35 Annealed at 800° F. for 2 hours	0.413	0.348	0.344	0.081

illustrations, similar results being indicated by other metals tested. It is seen that the commercially pure copper has a true local necking strain ϵ_n 78 times the true uniform ϵ_u. On the other hand, the brass shows the true uniform strain ϵ_u to be over 4 times the local necking strain ϵ_n. These characteristics are not nearly as well pictured by the ϵ_0 and q_0 values.

VI. THE EFFECTS OF VARIOUS MECHANICAL CONDITIONS AS REVEALED BY TRUE STRESS AND STRAIN PROPERTIES.

The true stress-strain tension test provides a convenient and rational instrument for the purpose of disclosing the effect of various conditions, both mechanical and metallurgical, on the fundamental physical properties of materials. It is the intention here to discuss first the effects of certain mechanical conditions such as high and low testing

temperatures, the velocity of testing and the specimen shape on these fundamental stress and strain values.

High Testing Temperatures.[7]

The ordinary short-time tension test carried out at elevated temperatures has assumed a less important role in recent years due to the realization of the practical importance of the long time creep test. In many problems, however, a knowledge of the short-time high-temperature properties is necessary in order to effect a rational solution. Various examples might be mentioned such as the hot-forming processes,

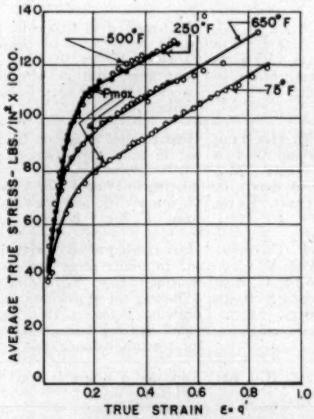

FIG. 5 - TRUE STRESS-STRAIN CURVES FOR S.A.E.-1112 STEEL AT VARIOUS TEMPERATURES.

rolling, forging, the welding problem if residual stresses are to be computed, the development of new high temperature alloys, etc. Most of the previous tension tests at elevated temperatures have been made with stresses and strains based on the original dimensions. Very little information is available in the literature on true stress-strain relations at elevated temperatures as determined in the tension test.

True stress-strain curves for several materials at both normal and elevated temperatures are shown in Figs. 5 to 8, inclusive. The chemical compositions and heat-treatments of these materials among others are listed in Table III. A summary of the effects of elevated

[7] C. W. MacGregor and L. E. Welch, "True Stress-Strain Relations at High Temperatures by the Two-Load Method," *Metals Technology*, September 1942, pp. 1–13.

TABLE III.

Materials Tested at Elevated Temperatures.

Material No.	Material	Heat-treatment	Test Temperatures, Deg. F.
1	S.A.E.—1112 steel	Annealed 1 hour at 1650° F. and slowly cooled	75, 250, 500, 650
2	S.A.E.—1045 steel	Annealed 1 hour at 1470° F. and slowly cooled	75, 250, 500, 650
3	A.T.V.—1 steel as rolled (Ni, 36; Cr, 11; Mn, 1.30; C, 0.30; P, 0.03 max.; S, 0.03 max.; Si, 0.20; Fe remainder)	As rolled condition; no heat-treatment	70, 250, 450, 600, 750
4	W-Ni-Cr iron (Cr, 12–14; Ni, 1.8–2.2; W, 2.5–3.5; C, 0.12 max.; Si, 0.50 max.; P, 0.025 max.; S, 0.025 max.; Mn, 0.50 max.; Fe remainder)	Heat-treated to 60,000 lb. per sq. in. proof stress by heating to 1800° F. for 30 min., air quenching, and drawing between 1230° and 1240°F. for 2 hours	70, 300, 580, 780, 950
5	Chrome iron (Cr, 11.5–13.0; Ni, 0.50 max.; Cr and Ni, 13.0 max.; C, 0.06–13 max.; Mn. 0.25–0.80; Si, 0.50 max.; P, 0.03 max.; S, 0.03 max.; Fe remainder)	Heat-treated to 60,000 lb. per sq. in min. proof stress, by heating to 1725° F. for ½ hour, air quenching, and drawing at 1240° F. for 2 hours	70, 250, 425, 780, 950
6	Turbine-bolt stock (Cr, 0.80–1.10; Mo, 0.45–0.65; V, 0.25–0.35; Mn, 0.40–0.70; C, 0.50 max.; P, 0.04 max.; S, 0.045 max.; Si, 0.20–0.35; Fe remainder)	Heat-treated to 100,000 lb. per sq. in. min. proof stress by heating to 1650° F., holding for 8 hours, oil quenching, and drawing between 1250° and 1260° F. for 8 hours, 1180° F. for 4 hours, furnace cool	70, 250, 400, 650, 970
7	Brass, ½ hard drawn (Cu, 62; Zn, 35; Pb, 3.0)	Annealed 2 hours at 800° F., and slowly cooled	75, 250, 500
8	Monel metal (Ni, 67–70; Cu, 26–30; Mn, 1.5 max.; Fe, 3.0 max.; Si, 0.25 max.; C, 0.25 max.)	As-rolled condition, no heat treatment	70, 250, 400, 600, 750

testing temperatures on the true stress-strain properties of several metals is included in Table IV.

An examination of this table together with Figs. 5 to 8 will disclose that: (1) the true stress-strain curves are linear from the maximum load point to fracture for each material and testing temperature; (2) the effect of testing temperature on the true stress at the maximum load and on the average true stress at fracture is different for most of the materials investigated; (3) although there are a few exceptions, the general effect of increasing the testing temperature on the true stresses at fracture is to either *reduce* them continuously or to first cause an *increase* and later a *decrease;* (4) the true uniform and local necking strains are affected differently by temperature; (5) the true

TABLE IV.

Summary of Effects of Elevated Temperatures on True Stress-Strain Properties

1 Material	2 Testing Temperature, Deg. F.	3 S_u True Stress at Maximum Load, Lbs. per Sq. In.	4 S_b Average True Stress at Fracture, Lbs. per Sq. In.	5 $q_u' = \epsilon_u$ True Uniform Strain at Maximum Load	6 $q_b' = \epsilon_b$ or True Fracture Strain	7 $q_n' = \epsilon_n$ or True Local Necking Strain	8 Min. Mod. of Strain Hardening $\frac{\partial S}{\partial \epsilon}$ Lbs. per Sq. In.	9 Intercept S_i, Lbs. per Sq. In.
S.A.E.—1112 steel	75[a]	83,800	117,800	0.243	0.871	0.628	56,800	69,000
	250[a]	112,000	127,800	0.183	0.525	0.342	47,700	99,000
	500[a]	110,000	140,800	0.194	0.631	0.437	64,600	98,500
	650[a]	93,200	131,400	0.180	0.817	0.637	61,700	83,500
S.A.E.—1045 steel	75[a]	109,700	142,700	0.197	0.571	0.374	89,700	91,000
	250[a]	101,900	136,000	0.168	0.547	0.379	88,300	87,500
	500[a]	114,100	131,500	0.136	0.343	0.207	84,700	102,000
	650[a]	107,100	120,100	0.147	0.313	0.166	73,000	95,000
A.T.V.—1 steel	70	140,600	192,000	0.195	0.663	0.468	106,200	120,000
	250	141,500	178,500	0.244	0.620	0.376	110,000	116,000
	450[a]	132,200	176,700	0.203	0.625	0.422	107,800	110,000
	600[a]	140,000	173,600	0.272	0.587	0.315	141,500	100,000
	750	137,800	185,500	0.263	0.631	0.368	127,000	105,000
W-Ni-Cr iron	70	139,000	198,000	0.103	0.718	0.615	91,200	133,000
	300	127,400	192,000	0.119	0.806	0.687	89,200	117,000
	580[a]	122,000	191,500	0.129	0.849	0.720	93,100	112,000
	780	118,200	194,000	0.121	0.845	0.724	98,000	110,000
	950	118,800	167,000	0.123	0.739	0.616	76,000	112,000
Chrome iron	70	114,900	192,800	0.094	1.150	1.056	74,500	110,000
	250	105,200	193,200	0.081	1.245	1.164	71,200	100,000
	425	101,700	190,200	0.0843	1.2553	1.171	71,200	96,000
	780	93,400	178,000	0.0695	1.1875	1.118	66,200	89,000
	950	93,600	157,000	0.0825	1.1115	1.029	60,000	89,000
Turbine-bolt steel	70	147,200	263,000	0.0649	1.0049	0.939	104,600	144,000
	250[a]	138,200	239,000	0.1025	1.0044	0.9022	103,200	128,000
	400[a]	138,500	226,500	0.0990	0.9460	0.8470	100,000	130,500
	650	107,500	220,000	0.0583	1.1643	1.106	98,000	104,000
	970	102,000	153,500	0.0469	1.359	1.312	64,000	98,000
Brass	75[a]	78,000	101,900	0.388	0.738	0.350	70,150	51,000
	250	77,800	93,800	0.429	0.660	0.231	66,200	49,000
	500	69,500	81,000	0.358	0.543	0.185	60,600	47,000
Monel metal	75	131,400	189,000	0.384	1.231	0.847	74,400	102,000
	250	117,000	199,000	0.330	1.252	0.922	87,200	90,000
	400[a]	112,200	196,200	0.315	1.262	0.947	85,100	87,000
	600[a]	120,000	191,400	0.369	1.099	0.730	97,400	82,000
	750	118,600	183,000	0.347	1.098	0.751	85,100	90,000

[a] Average of two or more specimens.

fracture strains and local necking strains are affected by temperature in a similar manner; (6) the minimum modulus of strain hardening disclosed a *decrease* with increasing testing temperatures for those metals for which the true fracture stress also decreased with higher temperatures; (7) the intercept S_i (used originally in reference (4) of

the linear portion of the true stress-strain curve on the stress axis of zero strain is *determined* principally by the relative values of the true stress at the maximum load S_u and the minimum modulus of strain hardening $\partial S/\partial \epsilon$. If both S_u and $\partial S/\partial \epsilon$ are increased by the testing temperature, S_i will either increase or decrease depending upon whether the effect of S_u on increasing S_i is greater or less than the effect of the larger value of $\partial S/\partial \epsilon$ on decreasing it respectively. When both S_u and $\partial S/\partial \epsilon$ are decreased by the testing temperature, S_i will decrease or increase depending upon whether the effect of S_u on decreasing S_i is

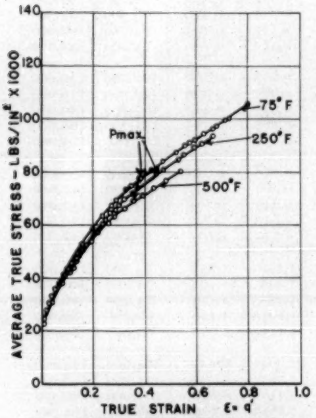

FIG. 6 - TRUE STRESS-STRAIN CURVES FOR BRASS AT VARIOUS TEMPERATURES

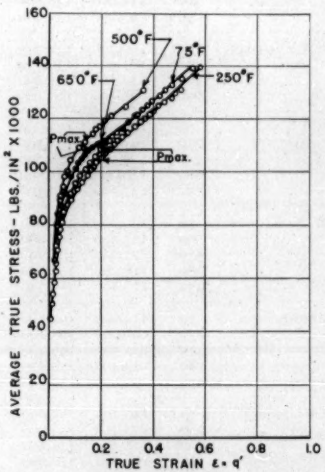

FIG. 7 - TRUE STRESS-STRAIN CURVES FOR S.A.E.-1045 STEEL AT VARIOUS TEMPERATURES.

greater or less than the effect of $\partial S/\partial \epsilon$ on increasing it respectively. In case the different testing temperatures produce changes in S_u and $\partial S/\partial \epsilon$ of opposite signs, the sign of the variation in the intercept S_i always follows the sign of the change in S_u.

As an illustration of item (7) consider the effect of testing temperature on the S.A.E.-1112 steel as listed in Table IV. An increase in the testing temperature to 250° F. increases the value of S_u from 83,800 lbs./in.² to 112,000 lbs./in.², and decreases $\partial S/\partial \epsilon$ from 56,800 lbs./in.² to 47,700 lbs./in.². Since these changes are of opposite sign, the value of S_i increases from 69,000 lbs./in.² to 99,000 lbs./in.², thus following the sign of the change in S_u. Likewise for 500° F., S_u decreases to 110,000 lbs./in.², and $\partial S/\partial \epsilon$ increases to 64,600 lbs./in.². These again are changes

of opposite sign so that the value of S_i follows the change in sign of S_u and decreases slightly. On the other hand, for 650° F., S_u decreases to 93,200 lbs./in.^{2} while $\partial S/\partial \epsilon$ also decreases to 61,700 lbs./in.^{2}. These changes are of the same sign, but the effect of S_u in decreasing S_i is

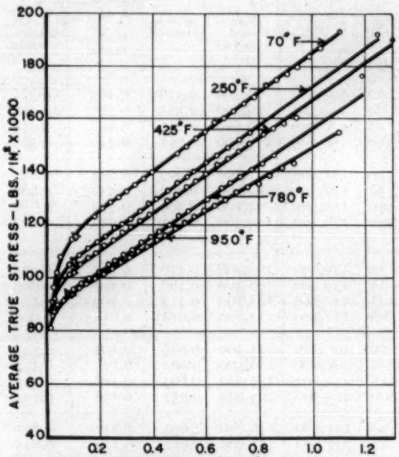

FIG. 8 – TRUE STRESS-STRAIN CURVES FOR CHROME IRON AT VARIOUS TEMPERATURES.

greater than the effect of $\partial S/\partial \epsilon$ in raising it, and consequently there results a net reduction in S_i to 83,500 lbs./in.^{2}.

Other values in the table follow these same general concepts.

Low Testing Temperatures.

Just as in the case of tension tests carried out at elevated temperatures, very little information is available on the effect of low temperatures on true stress and strain values. An investigation of this problem was undertaken in our laboratories recently by A. H. Prucknicki.[8] A new lot of materials were tested from 70° F. to − 300° F. (in liquid oxygen) and the true stress-strain curves obtained are shown in Figs. 9–13 inclusive. A summary of the effects of low temperatures on the true stress-strain values is included in Table V. At least two tension specimens were tested for each material at a given temperature. The S.A.E.-1112 and 1045 steels were tested in the fully annealed condition —with the remaining materials tested in the as-received state.

[8] A. H. Prucknicki, "The Two-Load Method For True Stress-Strain Curves At Subatmospheric Temperatures," M.S. Thesis, Massachusetts Institute of Technology, 1942.

TABLE V.

Effect of Low Temperatures on True Stress-Strain Properties
(Avg. of 2 spec. at each temp.)

Material	Temp. ° F.	S_b at Fracture, Lbs./In.²	S_u at Max. Load. Lbs./In.²	$\varepsilon_b = e_b$ Fracture	$\varepsilon_u' = \varepsilon_u$ at Max. Load (Uniform Strain)	$\varepsilon_n' = \varepsilon_n$ Local Necking Strain	Min. Mod. of Strain Hardening $\frac{\partial S}{\partial \varepsilon}$, Lbs. per Sq. In.	Intercept S_i, Lbs. per Sq. In.
Brass	70	100,600	74,400	0.576	0.195	0.381	63,600	62,200
	32	102,300	74,400	0.585	0.187	0.398	68,700	61,500
	−123	116,500	79,800	0.673	0.198	0.475	77,600	64,000
	−300	150,200	111,600	0.712	0.340	0.372	103,300	76,500
S.A.E.—1112	70	121,500	77,100	0.907	0.214	0.693	64,400	63,500
	32	122,300	82,100	0.920	0.232	0.688	56,750	69,700
	−119	135,500	94,100	0.906	0.250	0.656	62,900	79,000
	−300	119,400	119,400	0.095	0.0955	0.000	100,000 est.	110,000 est.
S.A.E.—1045	70	126,000	105,200	0.470	0.195	0.275	72,800	95,500
	32	130,400	108,400	0.460	0.195	0.265	70,600	98,500
	−123	142,500	125,700	0.414	0.203	0.211	78,600	110,000
	−300	132,700	132,700	0.0145	0.0145	0.000	——	——
S.A.E.—3140	70	197,500	141,300	0.648	0.105	0.543	102,900	129,000
	32	200,000	150,500	0.602	0.127	0.474	100,200	138,500
	−123	212,500	159,300	0.605	0.108	0.497	103,800	148,000
	−300	221,500	203,000	0.232	0.118	0.114	154,600	184,500
S.A.E.—4140	70	231,000	146,600	1.003	0.110	0.893	94,900	138,000
	32	234,500	151,200	0.972	0.124	0.848	98,600	141,000
	−125	242,000	168,300	0.915	0.127	0.788	109,900	153,500
	−300	294,000	219,600	0.661	0.147	0.514	145,800	200,000

It may be seen that a lowering of the testing temperature on these materials (1) causes an *increase* in the true stress at the maximum load in each case; (2) brings about an *increase* in the true fracture stress for temperatures down to − 120° F. (dry ice and alcohol) followed by a further increase for temperatures down to − 300° F. (liquid oxygen) for all materials tested with the exception of the S.A.E.-1045 and 1112 steels which show reduced values due to the embrittling effect; (3) in general *reduces* the true fracture strain for the steels but *increases* it for the brass; (4) generally *reduces* the true local necking strain for the steels but first *increases* and later *decreases* the local necking strain in the case of the brass; (5) reveals that while the true fracture strains for the steels at − 300° F. were always very much *less* than those at room temperature, the true uniform strains for the S.A.E. 3140, S.A.E. 4140 and the brass were *greater* at − 300° F. than at room temperature; (6) *increases* the minimum modulus of strain hardening for the brass and the S.A.E.-4140 at each of the temperatures tested, and first decreases and then increases it for the other materials; (7) in almost every case brings about an *increase* in the intercept S_i. As in the

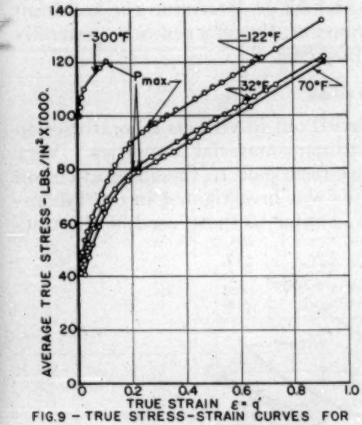

FIG.9 – TRUE STRESS-STRAIN CURVES FOR S.A.E.-1112 STEEL AT 70°F AND BELOW.

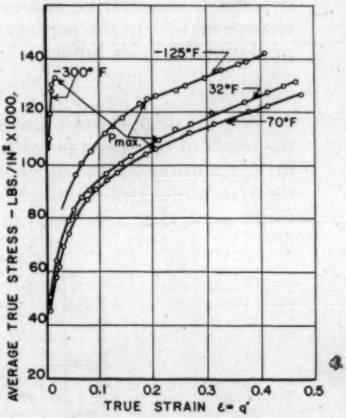

FIG.10 – TRUE STRESS-STRAIN CURVES FOR S.A.E.-1045 STEEL AT 70°F AND BELOW.

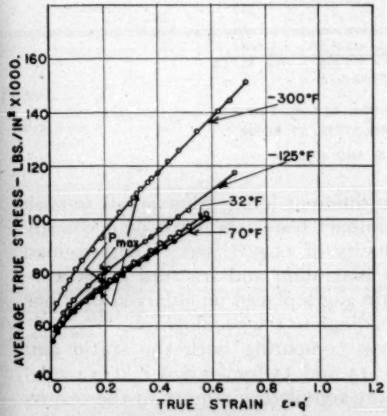

FIG.11 – TRUE STRESS - STRAIN CURVES FOR BRASS AT 70°F AND BELOW.

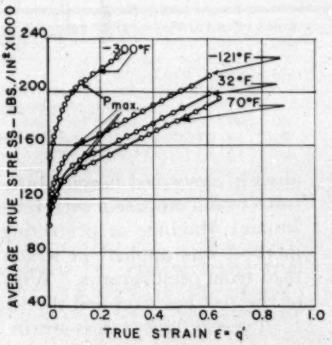

FIG.12 – TRUE STRESS - STRAIN CURVES FOR S.A.E.-3140 STEEL AT 70°F AND BELOW.

previous section (7) where the effects of high temperatures on S_i are described, the relative values of S_u and $\partial S/\partial \epsilon$ determine the resultant change in S_i. In the present case, however, the effect of S_u is generally predominant in its influence on the intercept S_i.

Velocity of Testing.

A great deal of work has been carried out in various laboratories on the effect of the speed of testing on ordinary material properties. Very little attention, on the other hand, has been paid to the speed effect on the true stress-strain properties. This was investigated in our laboratories some time ago [9] with materials similar to those used in the tests

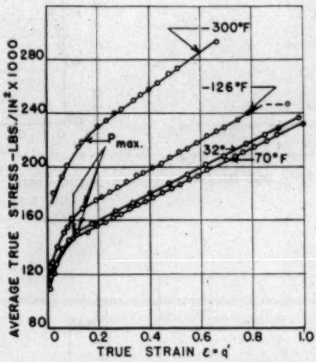

FIG.13- TRUE STRESS STRAIN CURVES FOR SAE-4140 STEEL AT ROOM TEMPERATURE AND BELOW.

already described herein, but from different lots. Slow speed tension tests were compared with tension impact tests conducted on a Charpy Impact Machine at a striking velocity of 11.5 ft./sec. The two-load method was applied in which the maximum and fracture loads were read from oscillograms. Wire strain gages placed on enlarged portions of the test bar supplied the load readings to the oscillograph.

Typical true stress-strain curves comparing both the static and dynamic values are shown in Figs. 14 and 15 for an S.A.E.-1112 steel and for a brass respectively. A more complete summary of the results is included in Table VI. The heat-treatment and composition of the materials is listed in Table VII.

[9] A. V. deForest, C. W. MacGregor and A. R. Anderson, "Rapid Tension Tests Using the Two-Load Method," Tech. Pub. 1393C, A.I.M.E., *Metals Technology*, December, 1941.

TABLE VI.

Summary of Test Results on the Effect of Speed of Testing on True Stress-Strain Values.

Material	Test Piece No.	Avg. True Strain Rate, Sec.$^{-1}$	Speed Ratio $\frac{v}{v_0}$	True Stress at Max. Load, Lbs./In.^{2}	True Stress at Fracture, Lbs./In.^{2}	True Fracture Strain $q_s' = e_k$	Ratio of q_s' to Static Value	Ratio True Stress at Max. Load to Static Value	Ratio True Fract. Stress to Static Value
S.A.E.—1112 Annealed	2G & 2J	903×10^{-6}	1.0	81,400	124,500	0.9481			
	2A	482	5.34×10^{5}	98,000	153,000	0.9632	1.015	1.29	1.230
	2B	410	4.54×10^{5}	98,000	127,200	0.9222	0.974	1.20	1.022
	2C	388	4.30×10^{5}	97,000	144,000	0.9302	0.983	1.19	1.157
	2D	384	4.25×10^{5}	90,000	136,000	0.9420	0.994	1.105	1.092
	2E	223	2.47×10^{5}	93,000	151,700	0.9497	1.000	1.142	1.218
	2F	230	2.55×10^{5}	89,000	138,800	0.8981	0.948	1.092	1.115
	2H	206	2.28×10^{5}	89,000	125,200	0.8755	0.924	1.092	1.005
	2I	222	2.46×10^{5}	90,000	141,000	0.900	0.950	1.106	1.132
Avg. 2A–2I			3.52×10^{5}				0.974	1.140	1.121
S.A.E.—1045 Annealed	1J	335×10^{-6}	1.0	104,200	144,800	0.8043			
	1C	358	10.69×10^{5}	115,000	165,500	0.8109	1.001	1.102	1.142
	1H	222	6.61×10^{5}	108,000	157,000	0.8545	1.06	1.036	1.085
Avg. 1C–1H			8.65×10^{5}				1.031	1.069	1.113
S.A.E.–3140 Hot Rolled	4M & 4I	387×10^{-6}	1.0	158,000	215,000	0.5800			
	4F	224×10^{-2}	5.79×10^{2}	158,000	236,000	0.6281	1.083	1.00	1.100
	4H	156×10^{-3}	4.06×10^{2}	156,000	233,000	0.6238	1.072	0.987	1.085
	4A	410	10.6×10^{5}	180,000	254,500	0.6355	1.097	1.140	1.183
	4B	457	11.8×10^{5}	180,000	257,500	0.6866	1.184	1.140	1.195
	4C	470	12.2×10^{5}	180,000	254,300	0.6811	1.172	1.140	1.180
	4D	185	4.78×10^{5}	170,000	232,500	0.6168	1.062	1.074	1.080
	4E	186	4.78×10^{5}	170,000	226,500	0.6323	1.090	1.075	1.050
	4G	178	4.60×10^{5}	170,000	228,200	0.6152	1.060	1.075	1.060
Avg. 4A–4G			8.12×10^{5}				1.102	1.080	1.116
Brass Annealed	4	422×10^{-6}	1.0	74,500	97,000	0.6840			
	6	186	4.42×10^{5}	85,000	144,000	0.8374	1.226	1.140	1.485
	7	188	4.46×10^{5}	86,000	134,200	0.8374	1.226	1.154	1.388
	9	196	4.66×10^{5}	86,000	130,600	0.8520	1.247	1.154	1.345
Avg. 6–9			4.51×10^{5}				1.233	1.149	1.406

A survey of Table VI will show that increasing the testing speed between these ranges and for these materials (1) *increases* the true stress at the maximum load by no more than 15 per cent (the average speed ratio varied from 350,000 to 1 to 865,000 to 1 in the different

TABLE VII.

Materials Tested, Speed Effect Tests.

Material	Heat Treatment
S.A.E.—1112 Steel	Annealed 1 hour at 1640° F. and slowly cooled.
S.A.E.—1045 Steel	Annealed 1 hour at 1450° F. and slowly cooled.
S.A.E.—3140 Steel	Hot rolled, tested as received.
Brass	(62 Cu, 35 zn, 3 Pb) ½ Hard, annealed 1 hour at 785°F. and slowly cooled.

materials); (2) *increases* the true fracture stress about 12 per cent for the steels and 40 per cent for the brass; (3) has no marked effect on the ductility as represented by the true fracture strain for the S.A.E.-1112 steel and the S.A.E.-1045 steel, but *increases* the true fracture strain by 10 and 23 per cent for the S.A.E. 3140 steel and the brass respectively; (4) although not shown in the table, an examination of Figs. 14 and 15 will bring out the fact that increasing the testing speed from the slow speed to the Charpy Impact speed *increases* the minimum modulus of strain hardening.

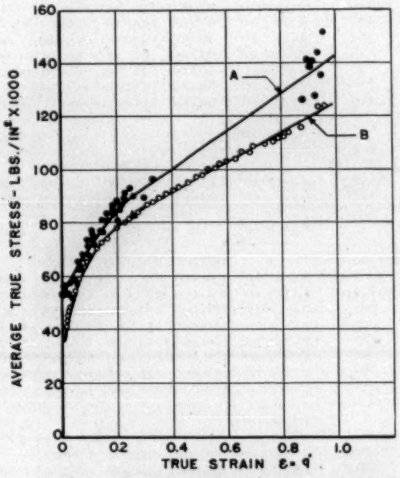

FIG. 14 TRUE STRESS-STRAIN CURVES FOR S.A.E-1112 STEEL FROM STATIC AND DYNAMIC TESTS USING THE TWO-LOAD METHOD.

NOTE- CURVE A AVERAGE FOR 8 TESTS—AVG. TRUE STRAIN RATE- 318 PER SEC.
CURVE B AVERAGE FOR 2 TESTS—AVG. TRUE STRAIN RATE- 903 X 10^{-5} PER SEC.

In a recent investigation at the Watertown Arsenal, Zener and Hollomon [10] have reported an essential equivalence between a decrease in the testing temperature and an increase in the over-all rate of deformation as it refers to the strength of certain metals.

Proportions of Test Specimen.

It is well known that even with a homogeneous metal, a change in the proportions of the test specimen will cause differences in the ordinary

[10] C. Zener and J. H. Hollomon, "Plastic Flow and Rupture of Metals," *Transactions of the Am. Soc. for Metals*, Vol. XXXIII, 1944, pp. 163–215. Also "Effect of Strain Rate Upon Plastic Flow of Steel," *Journal of Applied Physics*, January 1944, pp. 22–32.

ductility properties. It was deemed important to investigate the changes in the true stress-strain values brought about by using uniform test bars of various cross-sections. This was carried out [6] on a fully annealed low carbon steel. Particular attention was paid to the effect of different width to thickness ratios. Comparisons were made of the true stress-strain properties of standard 0.505" diameter test bars with flat bars having width to thickness ratios varying from 1 to 1 to those of 26 to 1. The effect of changing the length of the straight portion of

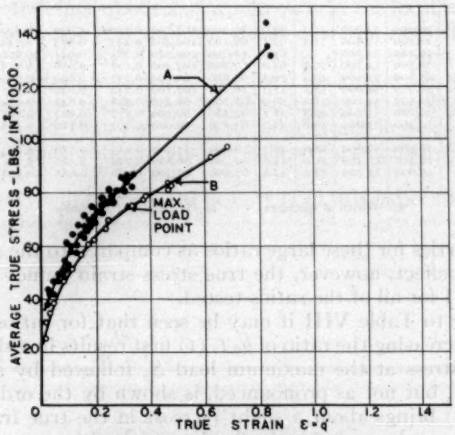

FIG. 15 COMPARISON OF TRUE STRESS-STRAIN CURVES FOR BRASS FROM STATIC AND DYNAMIC TESTS USING THE TWO LOAD METHOD.

NOTE- CURVE A AVG. FOR 3 SPECIMENS. AVG. TRUE STRAIN RATE- 190 PER SEC.
CURVE B AVG. FOR 4 SPECIMENS. AVG. TRUE STRAIN RATE- 422 X 10^{-6} PER SEC.

the flat bars was also investigated. The results are summarized in Table VIII.

The type of fracture of the flat bars changes from the typical transverse tensile fracture to a shear fracture inclined at about 25° to the horizontal at a ratio of width to thickness approximately 6 to 1. As the width becomes large compared to the thickness, the test no longer remains a simple uni-axial tension test even before any necking has taken place, but a bi-axial state of stress is introduced due to the transverse restraint. It can be shown that the transverse stress becomes equal to one-half the axial stress for large ratios of width to thickness. Consequently this materially affects the type of fracture. Hence considerable caution needs to be observed in any comparison of

TABLE VIII.

Effect of Proportions of Test Specimen on True Stress-Strain Values.
(Average of at least 2 specimens for each size.)

$\frac{b_0}{t_0}$	Ord. Tens. Props.					True Stress-Strain Props.						
	Series	Y. P. Lbs./In.²	T. S. Lbs./In.²	% $\frac{\epsilon_0}{2''}$	% Red. of Area	S_u True Stress at $P_{max.}$ Lbs./In.²	S_b Lbs./In.²	$\epsilon_u = q_u'$	$\epsilon_b = q_b'$	$\epsilon_n = q_n'$	Localized ϵ_b	Type of Fracture
Round 0.505″ dia.	VIII	30,400	53,700	37.7	63.9	66,900	107,700	0.2200	1.040	0.820		↑
1.10	IV	28,800	53,800	51.5	62.1	68,100	100,400	0.243	0.973	0.730		
1.30	IX	29,200	54,900		61.0	71,600	102,500	0.265	0.941	0.676		
2.00 I—8″	G.L.	30,500	53,500	50.2	61.0	67,800	103,400	0.237	0.950	0.713	1.028	
2.00 II—4″	G.L.	28,800	53,500	46.3	59.5	68,000	99,700	0.237	0.903	0.666	1.02	Tensile
2.00 III—2″	G.L.	30,950	55,000	58.1	57.3	70,800	102,100	0.244	0.839	0.595	0.958	Fracture
3.00	V	30,500	54,100	51.2	56.9	66,800	98,250	0.208	0.841	0.633	0.958	
4.00	VIa	30,200	53,800	46.5	58.1	64,500	99,500	0.177	0.882	0.705	0.950	
6.00	VI	30,500	53,000	49.0	52.7	63,800	90,000	0.192	0.760	0.568	0.971	↓
8.00	VIIb	30,300	50,000	38.0	48.7	70,100	77,400	0.313	0.516	0.203	0.775	↑
17.0	VIIa	28,400	51,300	41.0	44.0	69,300	80,800	0.248	0.527	0.279	0.747	Shear
26.1	VII	30,000	53,700	44.0	49.8	67,000	86,300	0.220	0.688	0.468	0.737	Fracture
												↓

b_0—Width of specimen. t_0—Thickness of specimen.

tensile properties for these large ratios as compared to the smaller ones. To show the effect, however, the true stress-strain values are recorded in Table VIII for all of the ratios tested.

Referring to Table VIII it may be seen that for ratios of b_0/t_0 less than 6 : 1, increasing the ratio of b_0/t_0 (1) first results in a slight *increase* in the true stress at the maximum load S_u followed by a *decrease* (a similar effect, but not as pronounced, is shown by the ordinary tensile strength); (2) brings about a slight *increase* in the true fracture stress S_b followed by a decrease for the flat bars; (3) with some variations in general tends to *decrease* the true fracture strain ϵ_b and the true local necking strain ϵ_n; (4) at first occasions an *increase* in true uniform strain ϵ_u followed by a *decrease*.

As compared to the round bars, the test pieces having a ratio of $b_0/t_0 = 1.10$ showed a slightly larger value of the true stress at the maximum load S_u, a smaller true breaking stress S_b, a somewhat larger true uniform strain ϵ_u, a smaller true local necking strain ϵ_n, and a slightly smaller true fracture strain ϵ_b.

On some of the flat test bars, a network of light lines were scribed a short distance apart before the test and the localized axial strain measured at fracture. This was done since the flat test bars start to fail at the center. The next to the last column of Table VIII shows that for ratios of b_0/t_0 less than 6 : 1, the localized true breaking strain was quite close to that obtained for the round bars.

For the flat bars having a ratio of $b_0/t_0 = 2$, the length of the straight uniform portion of the bar was varied from 2 inches to 8 inches. Table VIII also indicates that the true fracture stress S_b is left relatively

unaffected, but that both the true fracture strain ϵ_b and the true local necking strain ϵ_n are *reduced* as the straight portion of the test bar is decreased. The effect shown here is essentially that of the restraint introduced by the heads of the test bar. It is apparent that the restraining effect of the heads for short bars is reflected particularly in the true local necking strain.

As mentioned earlier, for ratios of b_0/t_0 greater than 6 : 1, the mechanism of failure changes rather abruptly to a shear type of fracture. The table shows that this tends to affect the various strain values quite differently. It brings about a sharp *decrease* in the local necking strain ϵ_n, an *increase* in the true uniform strain ϵ_u, and a net *reduction* in the true fracture strain ϵ_b. It appears to be quite reasonable for this changed type of failure to reduce the local necking strain since now the major deformation takes place by shearing on an inclined plane. It will also be noted that the localized axial strain in this case is about 75 per cent of that obtained for the transverse failures with ratios less than 6 : 1.

(A summary will be included in Part II of this paper to be published in the September issue.)

A Scientific Investigation of a Fake Cosmic Ray "Concentrator" or "Philosopher's Stone."—G. L. CLARK. (*Industrial Radiography*, Vol. II, No. 3.) Recently in one of the prominent cities of the State of Illinois, there were sold about seventy devices at $300 each for which was claimed cure of every type of disease. Institution of the campaign of sales began with a lecture in which the longest possible words descriptive of nuclear physics and cosmic rays, and invariably mispronounced, were strung together in a most fearful and mystifying manner with the result that each sentence was completely meaningless from the standpoint of scientific validity.

This device consisted of a brass capsule with one end conical and the other with a screw cap to which was attached a chain and safety pin. Inside of the brass capsule was a piece of glass capillary tubing sealed at both ends and containing a few milligrams of a white crystalline compound. In some supernatural way this device was to absorb the cosmic rays permeating the atmosphere, concentrate them, and then re-emit them in some highly beneficial form into the pathological lesion or organ over which the device was pinned. The immediate claim by numerous purchasers who were seeking anywhere and in any manner cure or alleviation of pain and suffering was miraculous improvement.

In the interest of protecting the people of the community against such an obvious fraud, the State's Attorney, at the instigation of one of the leading physicians, brought one of these "concentrators" to the Analytical Laboratory of the Chemistry Department of the University of Illinois in order to ascertain whether there was any ground whatsoever for the claims.

Through a series of ingenious experiments it was disclosed that the crystals were a barium chloride monohydrate, and that the capsules consisted of, in addition, a piece of brass, and a bit of glass tubing. Assuming that the total cost of the concentrator could not possibly exceed 50 cents, a few ounces of barium chloride on a pro rata basis would have a value of billions of dollars.

After all was concluded convincingly, the statement is then presented "So what? The point is, that these people are being cured by the use of this capsule." All of us who are interested in scientific truths wonder if after all 1944 is so far removed from the age of astrologers, medicine men and witches' brews.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

PLASTICS THROUGH THE LOOKING GLASS.

An unusual treatment of a fascinating subject is an article in the June 10 number of *Chemical and Engineering News* entitled "The Chemists' Wonderland," in which Gordon M. Kline, chief of the Bureau's plastics section, takes as his theme the analogies in "the Wonderland and Looking-Glass world of Alice's dreams to the realm of high polymer chemistry, typified by the plastics industry of today." Although it is essential that the public understand the limitations as well as the astonishing versatility of these new synthetics, a mere listing of present day types as compared with those available less than 20 years ago makes one agree with the Queen when she told Alice "Now, *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" Likewise, there is no difficulty in finding plenty to talk about, in applications of plastics, under any of the five subjects "of shoes—and ships—and sealing wax—of cabbages—and kings." A partial list of manufacturing groups that are consumers of plastics indicates many other ramifications in the uses for these materials. It is evident that to the animal, vegetable, and mineral kingdoms of previous centuries has now been added another—the synthetic kingdom—, and that in the list of materials of construction—metal, wood, concrete—there is now a new name—plastics.

A review of the manifold military applications of plastics forms a most interesting portion of the article. Future applications, as we may become familiar with them in the Looking Glass world of tomorrow, are shown to require almost a belief in the impossible—an attitude exactly like that of the White Queen who answered Alice's apparently sensible statement "One *can't* believe impossible things" with the remark, "I daresay you haven't had much practice. When I was your age, I always did it for half-an-hour a day. Why sometimes I've believed as many as six impossible things before breakfast."

With this approach not only six, but dozens of useful and beautiful things are visualized as contributions of plastics to better living. A scratch-resistant, nonfragile, heat-stable, weatherproof, transparent product—the result of the discovery by some chemist of the proper copolymer of styrene, methyl methacrylate, or other relatively simple compound with a cross-linking elastomeric monomer—can be expected.

* Communicated by the Director.

The low-pressure molding process developed during the present war to turn out helmet liners, aircraft and radio parts, small boats, and binocular cases may give us compact bath and kitchen units, light but strong furniture, economical two-seater utility automobiles and the light, tough, sound-absorbing structure of the family helicopter. "One thing is certain! The war applications of plastics have been amazing in scope but drab in aspect. The plastics of tomorrow will herald the return of spring to a color-starved world."

Having discussed types, present applications, and the probable future of plastics, Dr. Kline closes with the advice that Father William gave to the young man: "'I have answered three questions, and that is enough,' said his father; 'don't give yourself airs! Do you think I can listen all day to such stuff? Be off, or I'll kick you down stairs!'"

TEXTILE RESEARCH HEADQUARTERS AT PRINCETON, N. J.

An important step in the establishment of a central research organization for the whole textile industry was taken during May. The Textile Research Institute, Inc., purchased 5½ acres of land and an 18-room building at Princeton, New Jersey, to house its fundamental research laboratories, a textile library, and a graduate training program. It was announced that the research staff of the Textile Foundation, which has been located at the Bureau for 6 years, will move to this building as soon as it can be suitably equipped, and will serve as the fundamental research staff of the Institute as well as of the Textile Foundation under the direction of Dr. Milton Harris. Its activities will be aided by an Advisory Committee of outstanding scientists. The graduate training program will involve the training of a few picked college graduates each year for masters' or doctors' degrees in chemistry, physics, chemical engineering, etc., with textile specialization, using the facilities of Princeton University. Graduates must meet Princeton and Institute requirements and will be available for important positions in the textile industry.

Arrangements have also been made for the applied research work of the Institute under the direction of Giles E. Hopkins to take up quarters in laboratories to be leased from the Princeton Engineering School. Work will be conducted there, with the use elsewhere of such specialized facilities as may be needed.

A DAILY RECORD OF ULTRAVIOLET SOLAR AND SKY RADIATION.

In the July *Journal of Research* (RP1593), W. W. Coblentz describes a photoelectric ultraviolet intensity meter and automatic integrating and recording apparatus for measuring the biologically effective component of ultraviolet radiation, of wavelengths 3132A and shorter, from

the sun and the entire sky, incident on a horizontal plane, under various meteorological conditions. Methods of standardization, in absolute value, are described (*J. Research*, NBS **30**, 435 (June 1943) RP1542 and supplementary data). A continuous graphical record of the integrated daily total amount of biologically effective ultraviolet solar and sky radiation, observed during a period of almost 3 years (1941 to 1943), in Washington, D. C. is given. The monthly totals of biologically effective ultraviolet, in absolute value (milliwatt minutes per cm.^{2}) are also given graphically. On the clearest days the biologically effective component of ultraviolet radiation, of wavelengths 3132A and shorter, incident from the sun and the whole sky, at midday, ranges from about 180 microwatts per cm.^{2} (μw/cm.^{2}) in midsummer to about 30 μw/cm.^{2} in midwinter. A series of erythema tests is given, correlating the physical (radiometric) measurements with the physiological reaction of the untanned skin, which information is of interest in heliotherapy and bioclimatology.

THERMODYNAMIC PROPERTIES OF CIS-2-BUTENE.

Cis-2-butene ($H_3C.CH : CH.CH_3$) is one of the hydrocarbon compounds which occur in some of the chemical reactions involved in the manufacture of butadiene for synthetic rubber. A knowledge of the thermodynamic properties of these compounds is useful in controlling these chemical reactions and in testing the purity of the final products. Cis-2-butene is a gas at ordinary temperature. It boils at $+3.7°$ C. and freezes at $-138.9°$ C. In an investigation by Russell B. Scott, W. Julian Ferguson, and Ferdinand G. Brickwedde, reported as RP1592 in the July *Journal of Research*, the specific heat of solid cis-2-butene was measured from 15 degrees absolute up to its melting point. The specific heat of the liquid was measured from the melting point to room temperature. Vapor pressure and heats of vaporization were measured between $-78°$ C. and $+13°$ C. Using these data, tables of thermodynamic properties derived from the low temperature calorimetric data were extended to 1200° C. by calculations using spectroscopic data and the methods of statistical mechanics. The extent of the conversion of cis-2-butene to trans-2-butene, a closely related compound, also involved with cis-2-butene in the making of synthetic rubber, was calculated.

SPECIFIC HEAT AND ENTROPY OF SYNTHETIC RUBBER GR-S.

Because the synthetic rubber GR-S (government rubber-styrene type), which is the copolymer of butadiene and styrene, is the type of synthetic rubber being produced in much the largest quantity, this material was included in the Bureau's program of determining basic

thermodynamic properties of natural and synthetic rubber and of the components from which they are made. This program, which was initiated more than 10 years ago, has already included work on natural rubber, isoprene, and Hycar CR-15 synthetic rubber. Data obtained from these studies are needed in calculations having to do with: (1) chemical reactions in the manufacture of the monomers, (2) the reactions of polymerization, and (3) vulcanization and other reactions involving the polymerized material.

In the July issue of the *Journal of Research* (RP1595), R. D. Rands, Jr., W. J. Ferguson, and J. L. Prather describe measurements of specific heat on the synthetic rubber GR-S from −258° C. (15° K.) to about 60° C. The specific heat at 25° C. was found to be 1.894 international joules.gram^{-1}.degree^{-1}. A second-order transition, one which involves a marked change in the specific heat over a short temperature range, was discovered at about −61° C. Similar transitions have been found in Hycar CR-15 synthetic rubber at about −23° C., and in natural rubber at −70° C. It seems evident that the specific heat values just below the transition, and the transition temperature itself, depend on the thermal treatment of the sample.

The increase in entropy of the sample of GR-S studied from the absolute zero of temperature to 25° C. was calculated to be 1.824 international joules.gram^{-1}.degree^{-1}.

SYNTHESIS OF VITAMIN C FROM PECTIC SUBSTANCES.

Inasmuch as vitamin C deficiency retards the healing of wounds, and administration of vitamin C has been found to promote wound healing, a large demand for this substance has been created by the needs of the military forces. Although the vitamin is present in small quantities in fruits and vegetables, this source is not adequate and must be supplemented by the synthetic vitamin. The process now in use for the synthesis of vitamin C is long and complicated.

Since in many plant materials vitamin C is associated with pectin it seemed probable that a relation exists between galacturonic acid, the structural unit of the pectins, and vitamin C. Galacturonic acid, one of the more abundant plant materials, in the form of pectic substances comprises approximately 30 per cent. of the dry pulp which remains after extraction of sugar from sugar beets, and a large part of the pulp of citrus fruits and apples. Since the annual production of sugar beets alone is approximately 7,000,000 tons, there is an almost unlimited source of material suitable for the preparation of galacturonic acid.

For these reasons the preparation of vitamin C from beet pulp was investigated at the Bureau, by Horace S. Isbell, and a new process for the preparation of vitamin C was worked out. The pulp is treated with a commercial pectinase; the resulting galacturonic acid is separated

either in the form of sodium calcium galacturonate, or sodium strontium galacturonate. The salts reduced to salts of L-galactonic acid, which are converted to 2-keto-L-galactonic acid. The latter is lactonized and enolized to yield ascorbic acid (vitamin C).

As explained in the report on this work in the July *Journal of Research* (RP1594), a number of crystalline salts of galacturonic acid were prepared, 2-keto-L-galactonic acid and methyl 2-keto-L-galactonate were obtained in the crystalline state, and it was established that 2-keto-L-galactonic acid on lactonization and enolization yields vitamin C, rather than an isomer thereof. Electronic interpretations are presented for the conversion of methyl 2-keto-L-galactonate to ascorbic acid by basic catalysts, for the lactonization and enolization of 2-keto-hexonic acids by acid catalysts, and for the formation of furfural and reductic acids from pentoses, galacturonic acid, and ascorbic acid.

REACTIVITY OF AGGREGATE CONSTITUENTS IN ALKALINE SOLUTIONS.

A type of concrete failure observed in several areas in this country is now believed to be caused by excessive expansion due to reaction between certain types of rocks used as aggregates and the alkalies present in varying amounts in portland cement. The cause and the mechanism of this reaction are the subject of a study at the Bureau. As a part of this work, a paper prepared by Leonard Bean and J. J. Tregoning for publication in the *Journal of the American Concrete Institute* gives the results of an investigation of the reactivity of various types of rocks and minerals in alkaline solutions. For example, in an accelerated test at 122° C., in which the aggregate constituents were in contact with alkali hydroxide solutions, the order of reactivity was found to be as follows: Opal, chalcedony, pitchstone, rhyolite, basalt, magnesite, obsidian, calcite, limestone, dolomite, microcline, and oligoclase. The reactivities of these aggregate materials in hydroxide and hydroxide plus carbonate solutions at 21° C. fall in about the same order as in the accelerated test.

PERMEABILITY OF CONCRETE TO KEROSENE.

An error occurs in the item under this heading on p. 471 of THE JOURNAL OF THE FRANKLIN INSTITUTE (June 1944). It is stated that "powdered iron-type admixtures in the mortar coat reduced oil penetration, and one magnesium oxychloride type of coating looks promising if used where exposure to drying or to water is not excessive." This should read: "Powdered iron-type admixtures in the mortar coat did not reduce oil penetration; whereas one magnesium oxychloride type of coating looked promising if used where exposure to drying and to water is not excessive."

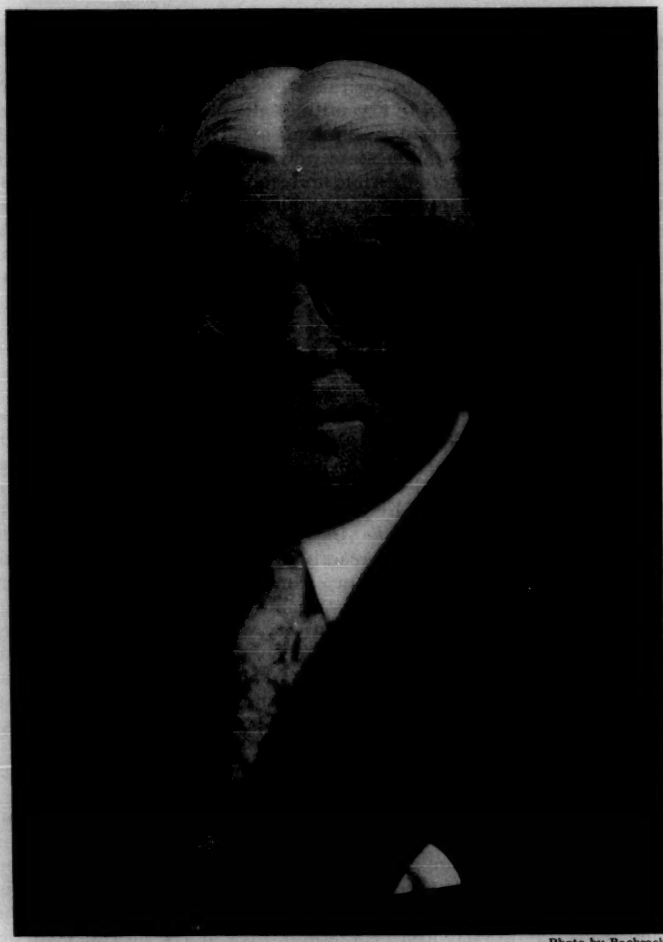

Photo by Bachrach

NATHAN HAYWARD, 1872–1944

THE FRANKLIN INSTITUTE.

RESOLUTIONS PASSED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF MR. NATHAN HAYWARD.

The Board of Managers of THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, having been advised by the President of the death on June twenty-first, nineteen hundred and forty-four, of their old and dear friend and fellow-Manager, Nathan Hayward, adopt unanimously the following resolutions:

RESOLVED: That we, the members of this Board, record our sense of great personal loss in the death of Nathan Hayward, our fellow-Manager, and also the deep sorrow we feel by reason of the termination of this fellowship which has endured for so many profitable and happy years.

Nathan Hayward's affiliation with the Institute began in 1913, when as an engineer rising fast in his profession he became an active member and immediately demonstrated generously contributive interest in its affairs. As time went on he accepted service on numerous stated and special committees; and in these all-important activities his particular devotion to the Committee on Science and the Arts, on which he served from 1916 to 1929, and to the Bartol Research Foundation Committee, of which he was a member for seven years and its chairman from 1942 until his death, were hallmarks of his high interest in the welfare and progress of the institution.

In 1929 Mr. Hayward became its President, at the threshold of a new era in its affairs marked by the undertaking to provide for the Institute a new home on the Parkway in Philadelphia, a vast memorial to Benjamin Franklin and a planetarium and museum of noble dimensions. In the labors of this development he played a principal part, and presided at the inauguration of the planetarium in 1933 and the museum in 1934. For eight years he continued in the office of President, and at the time of his death he was a member of the Board of Managers, on which he had served for twenty-seven years.

Just as his memory will live long with his associates at the Institute, so will endure the evidences of the wise planning and discerning judgments which he applied to the structure he loved so well. That there should ever be progress, but that never should there be departure from the finest concepts and traditions of the founders who in 1824 created The Franklin Institute, was his unfaltering creed.

AND BE IT FURTHER RESOLVED: That this minute be recorded by the Secretary and that a copy of it be sent to Mrs. Hayward in expression of our deep sympathy and of the memory which throughout the years we shall cherish of her husband, a gentleman who has set a worthy and encouraging pattern for those who follow in his footsteps.

July 14, 1944.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Wednesdays and Fridays from nine o'clock A.M. until five o'clock P.M., Thursdays from nine o'clock A.M. until ten o'clock P.M., Saturdays nine o'clock A.M. to twelve o'clock noon.

RECENT ADDITIONS.

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American Gas Association. Proceedings 1943. Twenty-fifth Annual Meeting. No date.
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KNAPP, ARTHUR W. Cacao Fermentation. 1937.
WEIL, B. H., AND VICTOR J. ANHORN. Plastic Horizons. 1944.

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HATSCHEK, PAUL. Electron-Optics. 1944.
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MITCHELL, DAVID R., Editor. Coal Preparation. 1943.

NAVIGATION.

BOK, BART J., AND FRANCIS W. WRIGHT. Basic Marine Navigation. 1944.

PHYSICS.

GLASSER, OTTO, Editor-in-Chief. Medical Physics. 1944.
GREENLEES, A. E. The Amplification and Distribution of Sound. 1943.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Urease Activity in Mammals.—LEOPOLD WEIL.* It is generally considered that urea is a waste product in the nitrogen metabolism of mammals, and is excreted as such in the urine. This assumption has been supported by the fact that most attempts to demonstrate urease activity in the animal body failed or only a very slight activity could be demonstrated (T. Tanaka, *Biochem. Ztschr.*, **37**: 249, 1911; W. Löb and S. Gutmann, *ibid.*, **41**: 445, 1912; L. Buetow, *ibid.*, **54**: 40, 1913; M. Loeper and J. Tonnet, *Compt. rend. soc. biol.*, **76**: 649, 1914; P. György and T. Stenström, *Biochem. Ztschr.*, **128**: 407, 1922; O. Steppuhn and X. Utkin-Ljubowzoff, *ibid.*, **146**: 115, 1924). A marked urease activity was found only in the gastric mucosa of dogs and cats (J. M. Luck, *Biochem. J.*, **18**: 825, 1924). In the present work evidence is presented that animal liver and animal and human red blood cells possess definite urease activity which can be demonstrated after autolytic processes take place.

EXPERIMENTAL.

Method. To 1 cc. of blood or tissue extract in the Warburg vessel were added 0.5 mg. of urea (dissolved in 0.5 cc. of water) and 0.5 cc. of a 0.08 per cent. thymol solution (for prevention of bacterial infection). The urea remaining after decomposition by the urease of blood or tissue was determined manometrically by the method of Krebs and Henseleit (*Ztschr. f. physiol. Chem.*, **210**: 33, 1932) and Weil and Russell (*J. Biol. Chem.*, **106**: 505, 1934). After incubation at 37° C. 0.5 cc. of 3N acetate buffer of pH 5 was added to the reaction mixture and 0.3 cc. of a urease solution † was placed in the side arm of the Warburg vessel. The latter was attached to the manometer and shaken at 37° C. to expel the blood or tissue CO_2. When no further pressure change occurred, the urease solution was tipped into the main chamber of the Warburg vessel and shaken until all unreacted urea present in the reaction mixture had been decomposed. For controls the experiment was run under identical conditions except that the urea was not added until immediately before the urea determination was made. The difference between these two determinations expresses the urease activity in terms

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† 3 g. "Arlco" Jack Bean urease preparation was extracted in 15 cc. of distilled water for one day, then centrifuged. To the supernatant liquid 1 cc. of 3N acetate buffer of pH 5 was added, and after one-hour standing the formed precipitate was removed by centrifugation. The supernatant solution was used for the urea decomposition.

of decrease of cmm. of CO_2 evolution. Complete decomposition of 0.5 mg. urea would yield 373.5 cmm. of CO_2.

Urease Activity in Blood. Oxalated blood taken from rabbit, rat or man does not show any changes in urea content upon incubation at 37° C. under aseptic conditions. Especial consideration was given to this point because of its importance in clinical investigation.

The oxalated blood was incubated under toluene at 37° C. and at various intervals the urea concentration was measured in 1 cc. of blood as described above. The results, presented in Table I, show that no

TABLE I.

Urea Concentration of Blood Expressed in mg. % Urea N.

	Incubation Time in Days			
	0	1	2	4
Rat Blood	12.34	12.09	11.98	12.22
Rabbit Blood	14.09	13.71	13.96	13.96
Human Blood	10.10	9.97	10.22	10.10

practical changes in the urea concentration were observed, thus indicating that no errors are introduced in clinical work even if blood samples are not investigated at once.

A different picture was obtained, however, if the blood cells were separated from the plasma. The plasma did not display any ability to decompose urea; the blood cells alone had this capacity. The ability of the blood cells to decompose urea could always be demonstrated if a 20-hour incubation time was used at 37° C. prior to the addition of urea. Table II presents a few typical examples. In some

TABLE II.

Urease Activity of Blood Constituents Expressed in Decrease of cmm. of CO_2.

	Whole Blood	Blood Cells	Plasma	Blood Cells and Plasma Recombined
Rat	0.0	79	0.0	0.0
Rabbit	0.0	142	0.0	5
Man	0.0	116	0.0	2

instances, however, urea decomposition could be observed without previous incubation time. Samples of oxalated blood obtained from rat, rabbit and man were centrifuged, the supernatant plasma removed and the blood cells washed twice with 0.9 per cent. NaCl solution. One cc. of whole blood and proportional amounts of plasma or blood cells (calculated from the ratio of the two after centrifugation in a graduated centrifuge tube) were incubated for 20 hours at 37° C. under sterile conditions. After autolysis the urea substrate was added

to whole blood, blood cells, plasma, and blood cells and plasma recombined in the original proportion. After an additional 20-hour incubation at 37° C., the remaining urea was determined. Table II shows that only the blood cells possess a urease activity, while the plasma was inactive in this respect. The addition of plasma to the blood cells inhibited the enzyme activity and this fact may explain why whole blood does not lose its urea content upon incubation.

In order to establish the fact that the decomposition of urea by the autolyzed blood cells was due to the urease activity, the ammonia formed simultaneously was also estimated. Washed blood cells obtained from 10 cc. of oxalated rabbit blood were made up to a volume of 10 cc. with distilled water. They were autolyzed under toluene for 20 hours at 37° C. and after that period 2.5 mg. of urea were added and the volume made up to 20 cc. After 20 hours' incubation at 37° C. the ammonia formed was distilled and titrated. Simultaneously the above method was compared with the manometric procedure. Urea nitrogen obtained by distillation was 1.21 mg., while the manometric method gave the value 1.18 mg. of N. Both values are in close agreement with the theoretical value of 1.16 mg. of urea nitrogen. Thus

TABLE III.

Urease Activity of Red Blood Cells Expressed in Decrease of cmm. of CO_2.

pH	4.1	5.1	5.9	7.0	8.2	9.5
cmm. of CO_2	50	86	101	128	22	19

the ammonia formed by the enzymatic decomposition of 2.5 mg. urea was completely recovered.

The Influence of pH on the Red Blood Cell Urease. Oxalated rat blood was centrifuged and the blood cells washed with 0.9 per cent. NaCl and made up to the original volume with distilled water. After 1-day incubation at 37° C. under toluene, portions of the hemolyzed blood cell solution were adjusted to various pH values with HCl or NaOH and checked with a glass electrode pH meter. For each determination an amount corresponding to 1 cc. of blood cell solution was used. After addition of 0.5 mg. of urea the total volume was made up to 2 cc. The urease activity was measured after 20 hours' incubation at 37° C. as mentioned before. Controls showed that no appreciable shift in the pH takes place during the incubation period. This is undoubtedly due to the buffering capacity of the reaction mixture.

As Table III shows, the pH optimum of the blood cell urease appears to be near neutrality.

Urease Content of the White Blood Cells. Since in all of the above measurements of activity in blood cells both white and red blood cells were present, it was necessary to investigate to what extent the white

cells contribute to this enzyme activity. White blood cells were prepared from 30 cc. of oxalated rabbit blood. After centrifugation the plasma was removed, and the blood sediment was washed twice with 0.9 per cent. NaCl solution in order to remove residual plasma. The red blood cells were hemolyzed then with 40 cc. of 1 per cent. acetic acid solution, centrifuged, and the white blood cell sediment was washed three times with 0.9 per cent. NaCl solution. The white blood cells obtained in this way were resuspended in 5 cc. of distilled water. One cc. of this white cell suspension (which represents 6 times the white cell concentration of 1 cc. of blood) was used for the urease determination as described before. In one experiment 20 hours' autolysis at 37° C. was used prior to the addition of the urea substrate, while in a second experiment no previous autolysis was used. The urea decomposition was measured after 20 hours at 37° C.

The results obtained, as shown in Table IV, indicate that the white blood cells possess only a slight urease activity and considering the fact

TABLE IV.

Urease Activity of White Blood Cells Expressed in Decrease of cmm. of CO_2.

	Without Autolysis	With Autolysis
Rabbit I	5	32
Rabbit II	7	26

that a sixfold concentration was used, it appears that the urease activity of the blood cells exists chiefly in the red blood cells.

After establishing the presence of urease in the red blood cells, the question was raised whether this enzyme activity might be found in any other part of the animal body. The following rat tissues were investigated: liver, spleen, kidney, gastric mucosa, pancreas, brain, thymus, muscle and Philadelphia No. 1 sarcoma. In organs such as liver, spleen and kidney where contamination with blood could be expected, the organs were sliced very thin and suspended several times in ice-cooled 0.9 per cent. NaCl solution in order to remove most of the blood cells. The tissue was then ground and a fine 1:10 suspension was prepared. One cc. of the tissue suspension was used for the urease determination. The reaction mixture was adjusted to pH 7. For each tissue the urease determination was carried out with and without previous autolysis at 37° C. prior to the addition of urea. The incubation time after the addition of urea was 20 hours at 37° C.

As Table V indicates, rat liver contains a considerable amount of urease, while spleen contains less. Some of the spleen urease activity may be due to the red blood cells, which were present in the tissue in spite of the precaution taken above.

TABLE V.

Urease Activity of Rat Tissues Expressed in Decrease of cmm. of CO_2.

	Liver	Spleen	Kidney	Gastric Mucosa	Pancreas	Brain	Thymus	Muscle	Phila. No. 1 Sarcoma
Without Autolysis	50	10	0	0	0	0	0	0	0
With Autolysis	179	55	4	5	0	0	0	0	0

The pH optimum of liver urease, shown in Table VI, is near neutrality as observed for the red blood cell urease. A liver suspension (1:10) was autolyzed under a toluene layer for 20 hours at 37° C. and the urease activity was measured in 1 cc. of suspension as described before. The pH was adjusted with the help of a glass electrode pH meter. By means of distillation with K_2CO_3 an equivalent amount of ammonia was recovered.

Experiments were also carried out to eliminate the possibility that dietary urease may be responsible for the observed urease activity. Five per cent. of "Arlco" Jack Bean urease preparation † was added to the standard Purina feed and was fed to 5 rats. The urease activity of the red blood cells and liver was measured as described previously

TABLE VI.

Urease Activity of Rat Liver Expressed in Decrease of cmm. of CO_2.

pH	4.0	5.7	6.3	7.1	8.3	9.5
cmm. of CO_2	0	68	102	162	64	0

after 5 days of feeding of the above diet. No significant differences could be observed if results were compared with those obtained with normal diet.

Summary. Evidence is presented that the red blood cells of rat, rabbit and man possess urease activity and that this activity is increased by autolytic processes. The urease activity of the red blood cells is inhibited by the plasma. The pH optimum of the red blood cell urease is near neutrality. White blood cells exhibit only a slight urease activity. Rat liver also contains urease which resembles the urease of the red blood cells in respect to the pH optimum and the activation by autolytic processes. Rat spleen contains a moderate amount of this enzyme; however, the possibility that the contaminating red blood cells may contribute to some extent to the activity was not excluded.

Kidney, gastric mucosa, pancreas, brain, thymus, muscle and Philadelphia No. 1 sarcoma of rat did not exhibit any urease activity even after autolysis.

BOOK REVIEWS.

PHYSICS, by Erich Hausmann and Edgar P. Slack. (United States Naval Academy Edition, Revised.) 857 pages, illustrations, 14 × 21 cms. New York, D. Van Nostrand Company, Inc., 1944. Price $5.50.

Physics is the foremost fundamental science. It is basic to the study of any type of engineering and is necessary in the professional education of a Naval Officer. In the latter case, however, some changes are advisable in the way of emphasis on various subjects and arrangement in order of presentation. In the United States Naval Academy the Midshipman advances from a course in physics to Marine Engineering, Electrical Engineering, Ordnance and Gunnery, Navigation and Seamanship, and Mathematics.

The book at hand is a revised text for students of the United States Naval Academy, the revision being by the Physics Staff of the Academy. The larger divisions are on mechanics, heat, sound, light, electricity and magnetism, and lastly a division on modern physics. Outstanding under mechanics are sections devoted to uniform circular motion, rotational motion and the gyroscope. There is perhaps a little more emphasis on these than in the usual text, as in the solution of problems in gyroscopic stability involving precession caused by external means such as changing course or rolling of a ship. Likewise under the subject of sound the discussion enters into sound ranging, or the location of the position of an enemy gun, and underwater sound detection and signaling. Necessarily much stress is laid on optics including binoculars, periscopes and stereoscopic vision and the coverage of interference and diffraction is most interesting. The treatment on electricity and magnetism is quite sufficient as a basic training including as it does electric cells, and the characteristics of alternating current circuits.

The last division on modern physics treats electrical discharge through gases as the first topic. Next, explanations are made of the theory of relativity and the quantum theory and these are called upon to explain additional phenomena under the headings of electromagnetic spectrum; spectral series; x-radiation; and radio activity and atomic disintegration.

While the subject is clearly presented and sympathy is shown in the situation of the student it is very evident throughout that there is no thought of making the study easier by a sacrifice in work. The number and type of problems for exercise are evidence of this and it is right to say that a thorough and lasting understanding will be had in their solution. Of great aid to the student are the answers to the problems in a section in the back, and this enlarges the usefulness of the book in the way of out-of-classroom study. The subject index also adds to the value of the book, for reference.

This book presents a well-rounded course in fundamental physics, quite complete and well presented.

R. H. OPPERMANN.

THE CONSTITUENTS OF WHEAT AND WHEAT PRODUCTS, by C. H. Bailey. 332 pages, tables and illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1944. Price $6.50.

The advance of chemistry in general has shown many times that lines of work which appear on the surface to be far afield from any other, actually border closely or are parallel to the work of another chemist. To relate the various research activities is one of the reasons for the monographs of the American Chemical Society. Another purpose is to furnish a well-digested survey of the progress already made, and report on the state of the art, which is not only a time saver but acts as a starting point for research and investigation. This book on the constituents of wheat is an American Chemical Society Monograph.

The author makes the distinction between descriptive biochemistry and dynamic biochemistry and insofar as is possible this book is a treatment on descriptive biochemistry only.

Written in a historic style it opens with early researches on wheat proteins beginning with Beccari in 1728, and considerable space is given over to the work of Osborne which served as a basis for later studies of other workers on the effort to develop quantitative fractionation techniques. Following this, prolamins of wheat, glutelins of wheat (the terms glutelin and glutenin being used as they were employed by the investigators at various times), water and salt soluble proteins, and crude protein and crude glutein are taken up in order. Exceptions to generalities with regard to the non-protein nitrogen of flour form an interesting chapter, well-digested from a number of sources. Starch is discussed separately, as are sugars, gums and cellulose. The presentation of the material on fats is divided into general treatment including the relative quantities of fats in wheat and flour, the properties and chemical constitution of the glycerides, phospholipids, and sterols. Considerable space is devoted to mineral analyses, the halogens, sulfur and selenium, and more brief and with less definiteness is that on acidity. A coverage on wheat and flour pigments precedes the last chapter of the book on vitamins of wheat and wheat products. The largeness of this subject makes it impossible to give adequate coverage in a book of this kind, so the author has wisely restricted treatment to wheat and its mill products. Even bread is omitted.

The work has an author and subject index in the back. The story is well presented. Where controversial points are revealed, opposing viewpoints are given. Incomplete work is recorded and labeled, and possibilities and probabilities for future researches are indicated. Throughout, the author has been very plain in his opinions. The work is of the high quality necessary for an American Chemical Society Monograph.

R. H. OPPERMANN.

HANDBOOK OF CHEMISTRY, Compiled and Edited by Norbert Adolph Lange. 2092 pages, tables and illustrations, 14 × 20 cms. Sandusky, Ohio, Handbook Publishers, Inc., 1944. Price $6.00. (Fabricoid.)

This well-known handbook is now in its fifth edition since the year 1934. So much more new and reliable data has recently come to light that it has been necessary completely to revise and extend material of previous editions. Perhaps the most important change in this edition is the complete revision of the table of Physical Constants of Organic Compounds. This table has been increased to include 6507 compounds with a corresponding list of more than 3500 synonyms. Each compound, wherever it is possible, is given its Beilstein Reference. Included in the new material are the following tables—flammable liquids; flame temperatures; plastics; periodic table (Deming); fluorescence of chemicals, minerals, and gems; and water for industrial use. Tables which have been extended or rewritten include common hazardous chemicals, vitamins, drinking water standards, trade names of chemicals.

The book contains a vast amount of information. It is condensed, arranged so that it can be located easily and quickly, and compiled from wide sources. The information reflects a huge amount of work and a fund of experience. Chemists, physicists, other scientists, engineers, and industrialists will find helpful and valuable information in this work.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Electronics; Today and Tomorrow, by John Mills. 178 pages, 14 × 21 cms. New York, D. Van Nostrand Company, Inc., 1944. Price $2.25.

Wood Chemistry, by Louis E. Wise, (Editor). 900 pages, tables and illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1944. Price $11.50.

Chemical Machinery, by Emil Raymond Riegel. 583 pages, photographs and diagrams, 16 × 23 cms. New York, Reinhold Publishing Corporation, 1944. Price $5.00.

Physics of the 20th Century, by Pascual Jordan. 185 pages, 14 × 22 cms. New York, Philosophical Library, 1944. Price $4.00.

CURRENT TOPICS.

A New Name Among Vinyl Resins.—M. Scott Moulton. (*Modern Plastics*, Vol. 21, No. 10.) Coincident with the development of a series of vinyl-vinylidene chloride copolymers, the name "Geon" has been selected to designate an entire family of polyvinyl resins presently including the new copolymers as well as two grades of polyvinyl chloride. These copolymers were developed specifically to furnish resins combining the unusual stability and chemical resistance of polyvinyl chloride with the solubility and plasticity essential to certain processing operations, particularly in the coating field. These copolymers round out the uses of vinyls to the point where they encompass nearly all possible methods of resin application. Compounded Geon resins can be calendered, extruded, molded, cast or applied to supplementary materials for extended applications by means of such methods as spreading or dipping, or by the use of various processes of impregnation.

R. H. O.

Refrigeration Aids Slime Control.—(*Engineering News-Record*, Vol. 132, No. 24.) Dehumidifying by cooling and then warming the air to the temperature of the surrounding structure has been found effective in reducing slime accumulations in the inspection galleries of mass concrete structures. S. O. Harper reports this new use for refrigeration developed in connection with the operation and maintenance of large dams and power plants of the Bureau of Reclamation, of which he is chief engineer.

During the humid season of the year, the normal temperatures of the galleries and of mechanical and electrical equipment within the dams are appreciably below the dew point temperature of the outside air. This leads to the condensation of moisture from air entering the galleries and its deposits upon the walls of the galleries and the mechanical and electrical equipment.

Moisture accelerates the growth of microscopic organisms and the formation of slime upon the walls of the galleries and causes the rapid deterioration of paint films with the consequent corrosion of metal surfaces. Also, moisture permeates and causes the breakdown of electrical insulation on wiring and equipment.

Since it is essential that a reasonable movement of air be maintained through the galleries, the complete solution to the problem of moisture condensation lies in the dehumidification of the ventilating air before it is introduced into the galleries.

One installation of equipment for this purpose is in progress at the Marshall Ford Dam in Texas, and a second is projected for the Grand Coulee Dam in Washington. The equipment is designed to perform the following functions:

(a) Filter the outside air.

(b) Pre-cool the air in extended surface coils with reservoir water. Some moisture is removed from the air by condensation in these coils.

(c) Sub-cool the air in extended surface coils with water chilled by mechanical refrigeration. Additional moisture is removed from the air by condensation in these coils.

(d) Reheat the air to normal gallery temperatures in extended surface coils with water warmed by heat rejected to the refrigerant condenser.

(e) Direct the processed air through the galleries in a predetermined path. This is accomplished by means of a centrifugal blower and a system of bulkheads in the galleries.

R. H. O.

Lubricating Oil.—(*Chemical and Metallurgical Engineering*, Vol. 51, No. 6.) By combining an Einstein equation with a Staudinger equation, chemists in the Richmond, Calif. laboratories of California Research Corporation recently developed a lubricating oil which thickens when heated and thins when cooled. This oil which to date is known only by its laboratory slang name, the "Oily Outlaw," was first developed as a theory on paper. By combining the two equations, it was proved that properly selected high viscosity material added to the oil would dissolve when heated and thicken the oil, and that the dissolved material would separate out again when the temperature dropped. The added substances are mostly resins many times as viscous as the oil itself; however, they are finely divided particles, each of which is composed of only a few thousand molecules. Subsequent tests showed that at ordinary temperatures the particles remain suspended in the oil and do not affect its viscosity, but when the oil becomes heated the particles gradually break up. The higher the temperature the greater the breakage, until finally they are reduced approximately to molecule size. In that state they form a solution with the oil and contribute greatly to its viscosity. When the oil cools, the molecules slump together again and become particles suspended in the lubricant and the oil returns to its former low viscosity state. While officials have pointed out the new oil is still a laboratory curiosity, the hope has been expressed that some day it may be instrumental in solving the problem of lubricating equipment that necessarily operates through wide temperature ranges.

R. H. O.

ARMY AND NAVY NOTES.

Metal Spraying Costs Reduced.—FRED C. GANDERT. (*Iron Age*, Vol. 153, No. 26.) Using natural gas and oxygen for the metal spraying of zinc or copper on light sheet metal at the Westinghouse plant at Mansfield, Ohio, has resulted in a 15 per cent. reduction in fuel cost and higher spraying speeds.

This natural gas and oxygen process was employed when an increase in the production schedule of Navy plane radios required a corresponding increase in metal spraying facilities. Although oxy-acetylene for the metal spraying of sheet metal has several advantages, it has one disadvantage on a large production set-up. Underwriters specify that acetylene pressures must be held to a maximum of 15 lb. and this pressure limitation was a definite handicap in trying to increase the spraying capacity of the guns.

After making a study of the various fuel gases that could be used in metal spraying of zinc and copper it was decided to install a booster pump in the plant's natural gas line and pipe the gas to the metal spray booths. The booster pump is capable of supplying the spray guns with pressure up to 150 lb. It has been found, however, that a 50 lb. pressure apparently is the most efficient and economical to use. Gas pressures higher than that do not increase the number of pounds of metal sprayed per hour in proportion to the amount of gas and oxygen consumed.

A further advantage was obtained by installing an oxygen manifold and piping the oxygen to the metal spray booths, thereby eliminating any cylinder handling by the operators.

Lower fuel costs can be achieved, although a natural gas and oxygen flame does not have as high a flame temperature as oxy-acetylene, because a higher pressure can be used to offset this B.t.u. loss.

Using high pressure natural gas also provides a wide range of spraying speeds and makes possible a 15 per cent. saving in operating time. The number of square feet of metal that can be sprayed per hour is governed by how many pounds of wire can be melted at the gun.

R. H. O.

Fuel Tablet.—(*Chemical and Metallurgical Engineering*, Vol. 51, No. 6.) A new type of fuel tablet for heating the meat component of combat rations or heating water in a canteen cup in the field for coffee or cocoa has been developed by the Quartermaster Corps in collaboration with the Office of Scientific Research and Development, the War Department has announced. The tablet is a synthetic compound, known as trioxane, with a binder to hold it in solid form when burning, and coloring matter to distinguish it as non-edible. It has several advantages over the previously developed square candle, made principally of paraffin, such as a fast rate of heating, light weight, compactness and a blue flame of low luminosity. The tablets are flat, weigh slightly more than one ounce, and each will heat an individual meal from the "C" or "K" combat rations in 6 or 7 minutes. The new fuel is substantially free from smoke-producing ingredients and will not smudge the bottom of the vessel being heated. It is packed in a moisture-proof foil envelope and may be burned in a small trench or behind a small shield to protect the flame from wind.

R. H. O.

Condition Aircraft Plant By Centrifugal Machines.—(*Refrigerating Engineering*, Vol. 47, No. 6.) The construction of giant aircraft plants in wartime America has set no more significant pattern for future industry than the increasing use of complete, year-round air conditioning as a major production tool. Typical of the trend is the new windowless, 11-acre plant of Jacobs Aircraft Engine Company, at Pottstown, Pa. Its air conditioning boosts production by eliminating time and material losses due to dust and variations in the temperature and humidity of the air.

Indicative of the size of the system and the job it does, is the fact that it requires five Carrier centrifugal refrigerating machines, supplying a cooling

effect equivalent to the melting of 3000 tons of ice a day. Among the primary production benefits of the air conditioning at the Jacobs plant are the following:

1. The obvious advantage of comfortable working conditions where dust, internal heat load, fumes from solvents used in polishing, and vaporized cutting oil would otherwise harass workers.

2. Overcoming measurement inaccuracies by keeping the temperature constant. Gages are applied in the same climate in which they were calibrated. Parts are assembled at the same temperature at which they were machined. The number of rejects has consequently been cut sharply.

3. Damaging moisture is not left on sensitive metal parts because humidities are held constant at a predetermined level. Workers' hands are thus kept free of perspiration. This function also cuts down rejects and spoiled parts.

4. Corrosion and erosion, due to dust on metal surfaces or inside intricate mechanisms, have been reduced to a minimum, because the system cleans the air. Again production has benefited.

Besides the machines which supply chilled water to the air conditioning system, ten other refrigerating machines are used to preserve food served in the plant cafeteria.

R. H. O.

Endless-Chain Monorail System 2 Miles Long.—ROBERT WELLS. (*Steel*, Vol. 115, No. 1.) In prewar days, extensive conveyor systems like the kind which in peacetime helped turn out better automobiles more rapidly were unknown in airplane factories, for in those years an order for 50 planes was considered unusually large. With the almost overnight expansion of the aircraft industry under war's impetus, the situation changed. But many plane builders, believing that aircraft parts are too large and of too great irregularity to be handled by conveyors, hesitated to install such mechanical devices.

One of the largest airplane factories to adapt conveyors to aircraft work with a great deal of success is the Columbus, Ohio plant of Curtiss-Wright Corp. where the Navy dive bomber, the Hell Diver, is manufactured.

Built shortly before Pearl Harbor, and since greatly expanded, the factory is one of the most modern plants of its kind in the world. It extends over such a large area that the problem of transporting parts was a serious one. After struggling along with a system of intra-plant trucks for some months, engineers came to the conclusion that installation of an extensive conveyor system was necessary to speed up production, which in early days of the plant's existence was somewhat disappointing.

There was hesitancy on the part of a minority of the Columbus plant's executives to recognize the desirability for conveyors. Most of these men have changed their minds now and are enthusiastic boosters for the plant's intra- and inter-building mechanical conveyors. Notable also is the fact the Columbus plant has set an unbroken record of meeting its production quotas each month since installation of these devices.

Most impressive of the eight types of conveyors now in use is a recently installed overhead monorail endless-chain conveyor which serves a manufacturing area ½ mile long and ⅛ mile wide. Conveyors in each of the two main factory buildings meet an inter-building conveyor at a central control

station so that a part may be dispatched by conveyor to any point in the manufacturing area. Material or parts routed from one building to another are transferred at this station. Push button mechanism, with a control for each line conveniently mounted above operator's head, can be used to start or stop conveyers at will. In case of an emergency, conveyor can be locked and cannot be started again except from this control station, thus minimizing danger of accidents if repairs must be made.

R. H. O.

Tests Reveal Performance of America's Most Powerful Single Acting Diesel.—(*Power*, Vol. 88, No. 7.) Exhaustive shop tests of the most powerful single acting diesel engine yet built in this country indicate ability to operate successfully, with good fuel economy, on heavy low grade fuels. This 6000-shp. 2 cycle mechanical injection 9 cylinder 29×40 in. engine was developed by the Nordberg Mfg. Co. for direct drive marine use and will be installed in one of the Maritime Commission's Victory Ships. Units of similar design, in sizes from 4000 shp. (6 cylinders) to 8000 shp. (12 cylinders), will be available for ship propulsion in single or twin engine direct drive and twin engine geared single screw combinations, as well as for stationary applications ranging from 3000 to 6000 kw.

For maritime application, the unit operates at 160 r.p.m. and the 6000 hp. normal rating is obtained at 62 psi break mean effective pressure. An overload of 10 per cent. can be carried continuously and 25 per cent. for two hours. The standard speed of 160 r.p.m. is low enough for direct drive with suitable propeller efficiency in single or twin screw ships, but the engine may also drive through reduction gears with optimum propeller efficiency. Engine design permits operation through the entire speed range without harmful peaks of torsional vibration. For stationary service the standard speed is 164 r.p.m. at which the rating is 500 kw. per cylinder.

R. H. O.

Removing Rust and Corrosion from Metal Surfaces.—(*Machinery*, Volume 50, No. 19.) The method used for removing rust or corrosion will depend on the depth of the corrosion and the type of surface needed after the corrosion has been removed. Scratch-brushing is probably the simplest method, but may leave the surface quite rough. Sand-blasting is effective in cleaning metal surfaces preparatory to the application of most protective coatings under conditions where pickling or other methods of cleaning are impractical or inadequate; sometimes chilled steel shot is used instead of sand. But this method does not remove tightly adhering mill scale nor clean the crevices as well as pickling. It may leave the metal with a rather smooth and less desirable finish.

Corrosion in the form of scale can be removed by pickling, using a 5 per cent. solution of hydrochloric acid or a 5 to 10 per cent. sulphuric acid solution. The bath is kept at about 180 degrees F. by the injection of steam. The disadvantage of pickling is that a large per cent. of the scale comes off first, and while the remainder is being removed, the bare metal exposed to attack is eaten away more rapidly.

It is possible also to cause brittleness of the metal, due to the absorption of hydrogen. If this occurs, the ductility of the metal may be largely restored by heating it in water at the boiling point for several hours in an open tank. Some organic compounds, such as sizing, off-grade flour, or bran, added to the pickle solution, help to keep down acid fumes and to protect the exposed metal from overpickling, without reducing the rate of scale removal. Continued agitation and aeration of the pickling bath save time and the amount of acid used.

Electrolytic pickling may be used for special work. The surface of the metal may be cleaned by making it the anode or the cathode (with an insoluble anode) in an electrolyte through which a current is passed. When used as the anode, the rapid solution of the metal and oxygen liberated on the surface loosens the scale. When used as the cathode, the hydrogen deposited on the surface reduces the oxide scale and aids in removing it. This hydrogen may make the metal more brittle than when cleaned at the anode, but the metal is cleaned this way without loss of weight.

Slight amounts of rust may be removed by the use of oil and crocus cloth. For removing a very light coating of rust, there are solutions available on the market that are quite effective. In no instance can it be expected that a smooth, polished surface will be left after any of the above treatments, as the rust coating is never eaten away evenly, and there will be deep pits in some spots. However, surface corrosion should be removed before attempting to cover with any preservative coating, as otherwise the corrosion will continue under the coating, which may cause the coating finally to peel off.

To summarize, corrosion removal may be accomplished by scratch-brushing, sand- or shot-blasting, pickling, electrolytic pickling, or by the use of certain special solutions; but none of these methods will leave the metal surface in its original condition. This is a point that should not be overlooked.

R. H. O.

New Cargo Planes for Navy.—(*Blast Furnace & Steel Plant*, Volume 52, No. 6.) The Budd Conestoga, first large size airplane of stainless steel construction ever to be put into production, has been accepted by the Navy after trial board tests.

The first of the airplanes has been turned over to the Naval Air Transport Service for use in transporting vital cargo to the fleet.

Designated the RBI Flight Ship, the Conestoga was designed and is being produced by the Edward G. Budd Company of Philadelphia, Pennsylvania. It is the first airplane obtained by the Navy which was designed especially for cargo carrying. Other Navy cargo planes are adaptations of combat aircraft or passenger transports.

The Conestoga is a high-wing monoplane, 68 feet long, with 100-foot wingspread, and is powered by two Pratt and Whitney engines with a take-off power of 1,200 horsepower each.

Except for plywood doors and floors, the airplane is constructed entirely of stainless steel. The steel skin thickness varies from .008 of an inch upward and is joined together by spot welding.

The airplane is built around a cargo compartment 25 feet long, eight feet wide, and eight feet high. A cargo hatch opens at the rear, below the upswept

tail. The hatch drops down to form a ramp over which the cargo may be loaded.

Cargo capacity is 10,400 lbs. The plane will carry one ambulance, or two jeeps. As a personnel transport it may be fitted with 24 seats. For evacuating wounded, it carries 24 stretchers.

Paratroops may be launched simultaneously through doors on both sides of the fuselage, while at the same time the troops' supplies may be dropped through the rear hatch.

Cruising speed is 165 miles per hour. Flight range, at economical cruising speed, with maximum load, is 600 miles. Maximum range is 1,700 miles, and this may be extended to 2,500 miles by use of auxiliary fuel tanks.

In tests, the plane took off with full load after a run of 920 feet.

The Budd Company is building the Conestoga in a new plant under a Navy contract. Part of the output of the planes will go to the Navy, and part to the Army.

R. H. O.